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December 1960

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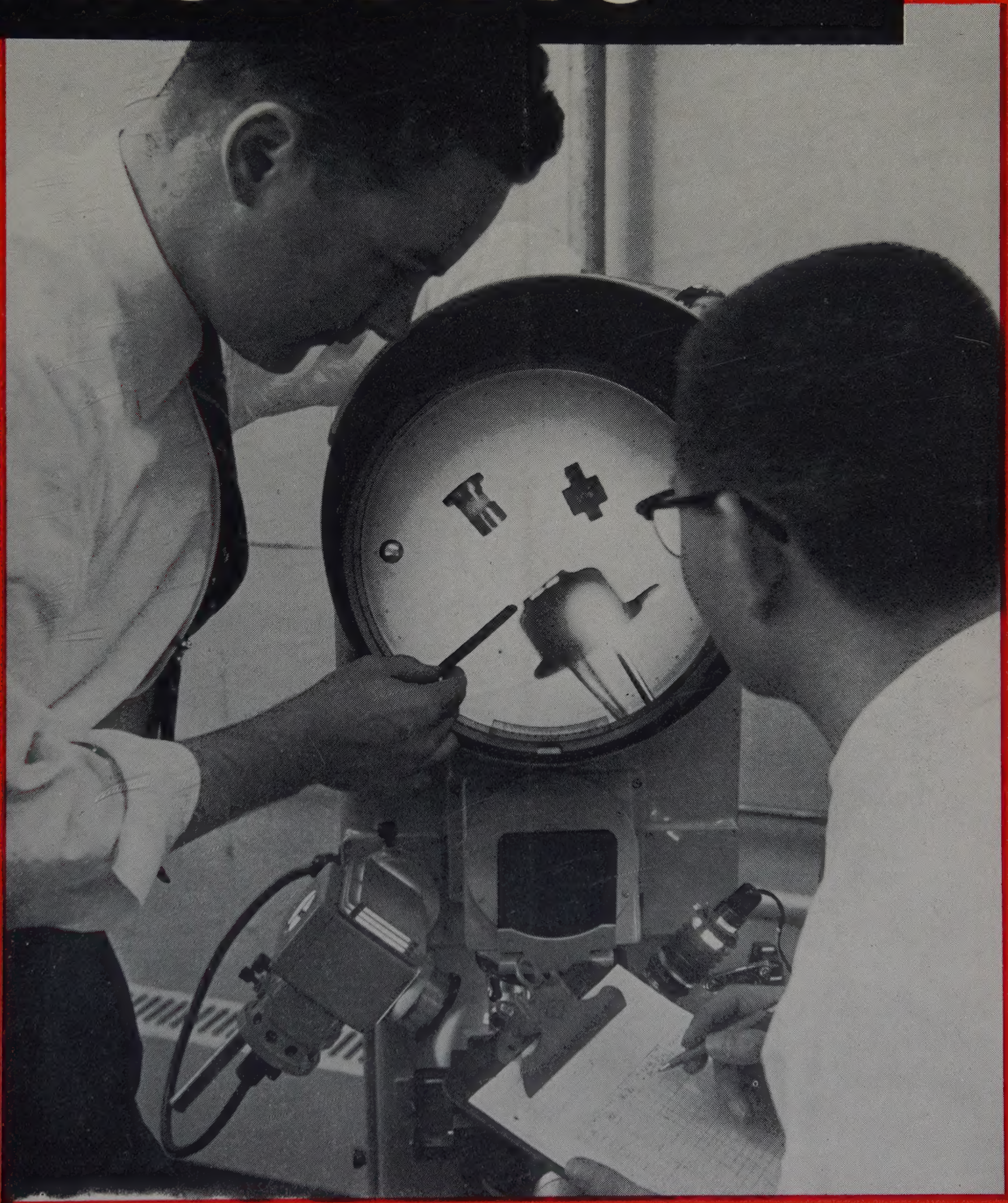
# SEMICONDUCTOR PRODUCTS

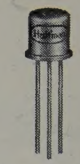


DIODE COMPARISON WITH OPTICAL COMPARATOR

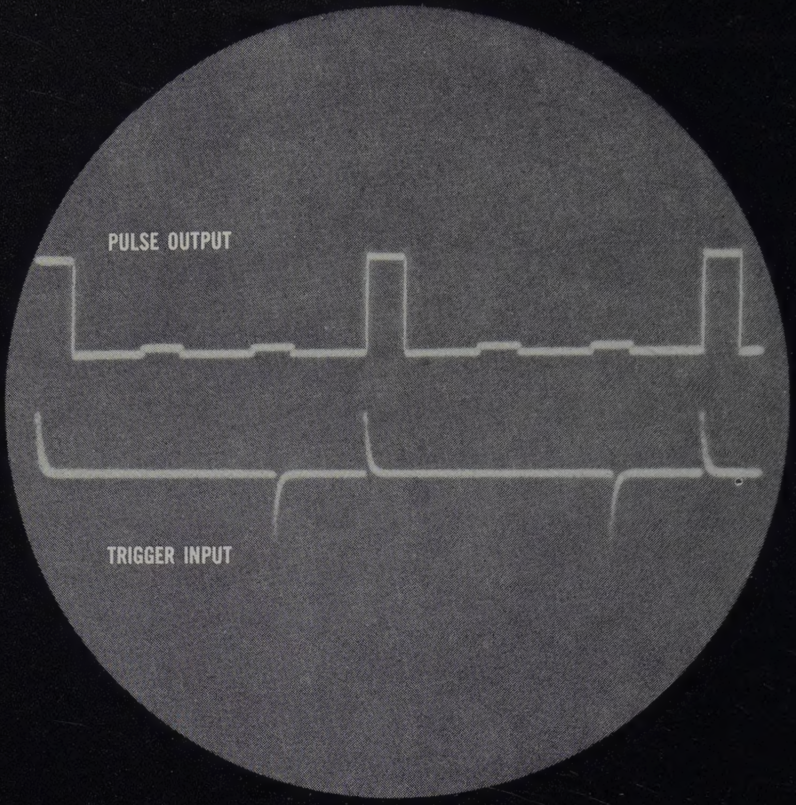
**Tunnel Diode Monostable Multivibrator**

**Survey of Semiconductor Devices and Circuits in Computers**

**Photovoltaic Conversion of Solar Energy**

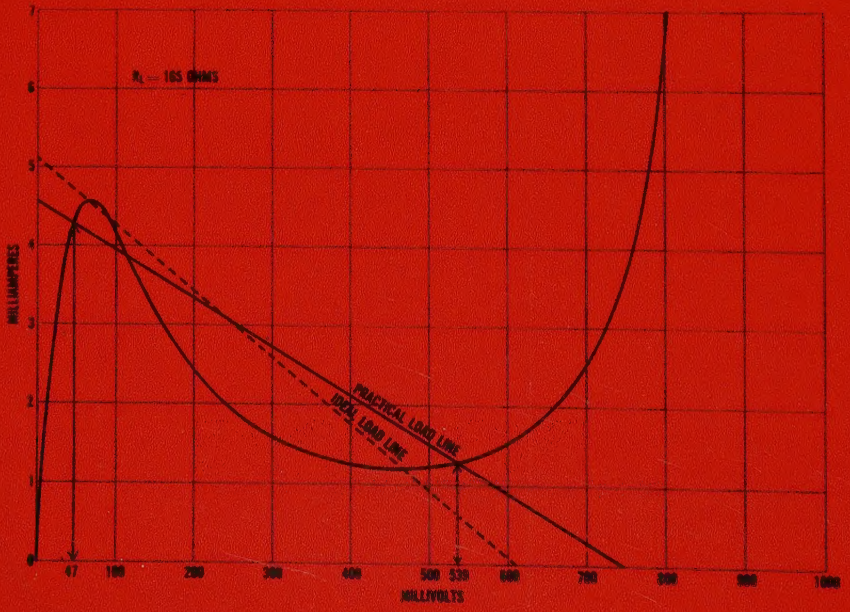


TO-18 Case




Input and output wave forms for circuit shown below

Switching circuit


Practical load line indicates operation with optimum stability

# –FOR THE HIGHEST 0/1 VOLTAGE RATIO

# –FOR THE WIDEST RANGE OF PEAK CURRENTS

## ...SPECIFY HOFFMAN SILICON TUNNEL DIODES

Now you can specify tunnel diodes with $V_V/V_P$ ratio as high as 7.0:1 and with peak currents ranging from 470 $\mu$A to 100 mA ... and from a single source! Only Hoffman offers this great a selection plus the uniformity and proven performance of silicon. Guaranteed tolerances of $\pm$10% and $\pm$2% enable you to design to new standards of precision and reliability.

Whatever your circuit requirements, there is now a Hoffman silicon tunnel diode to meet them. For details, request Hoffman Data Sheet No. 137-760 STD.

| Type Number | Peak Current |
|---|---|
| 1N2928 | 470 $\mu$A |
| 1N2929 | 1 mA |
| 1N2930 | 4.7 mA |
| 1N2931 | 10 mA |
| 1N2932 | 22 mA |
| 1N2933 | 47 mA |
| 1N2934 | 100 mA |

"A" versions available with $\pm$2% tolerance.

**You can use Hoffman tunnel diodes confidently:**

- **when temperature requirements are** severe—units are stable from −85°C to +200°C.
- **to obtain maximum performance in switching circuits**—units have highest $V_V/V_P$ ratio of all tunnel diodes ... up to 7.0:1.
- **for predictable circuit operation**—units have extremely uniform electrical parameters.

**Custom-engineered units available from 100 $\mu$A to 1 A**

IMMEDIATE DELIVERY IN QUANTITY FROM DISTRIBUTORS OR FACTORY.

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***Semiconductor Division***

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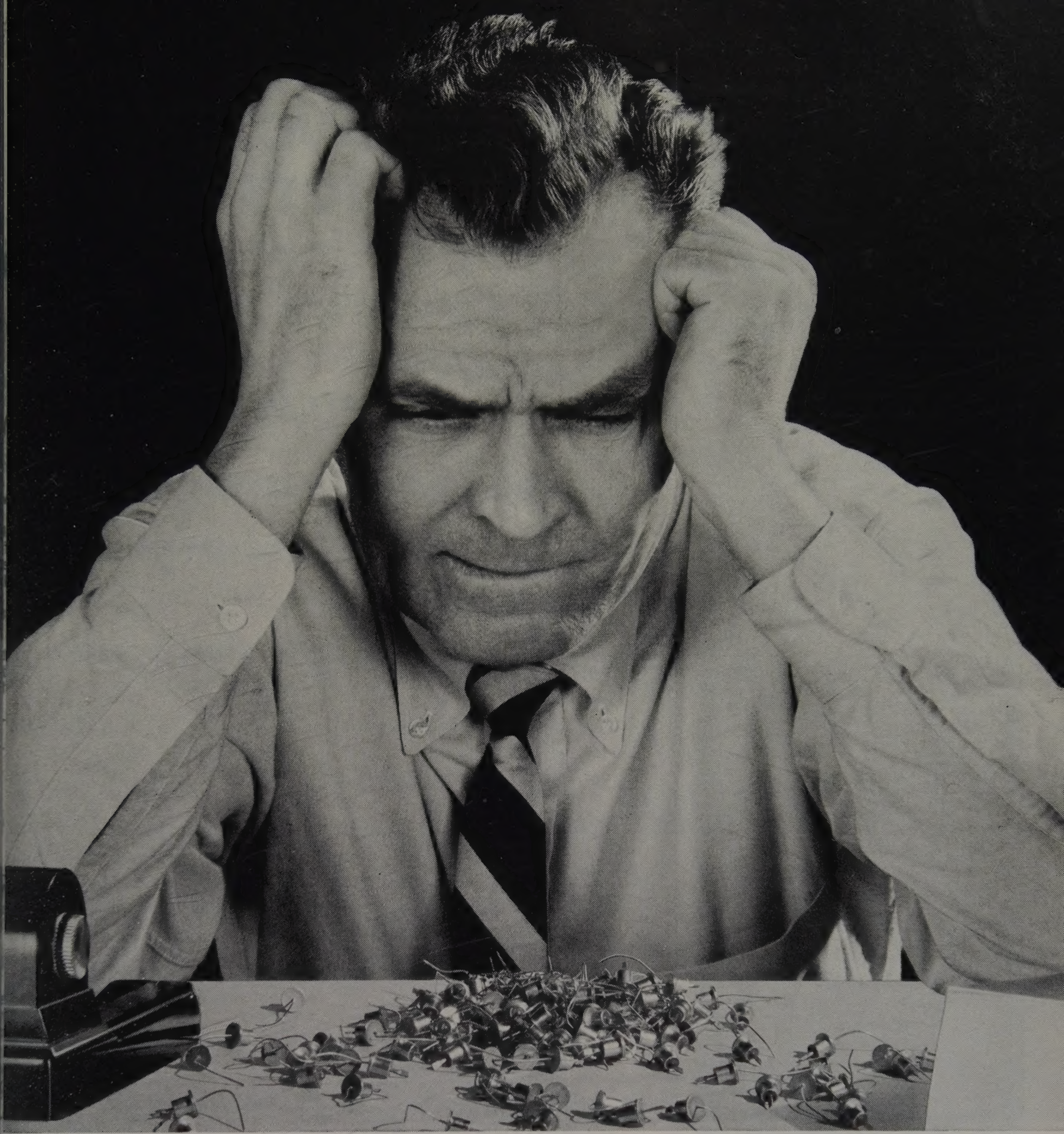


# SEMICONDUCTOR PRODUCTS

SANFORD R. COWAN, Publisher

December 1960 Vol. 3 No. 12

## CONTENTS



**SEMICONDUCTOR PRODUCTS assumes no responsibility for company credit affiliations claimed by authors for byline purposes.**

**Front Cover**

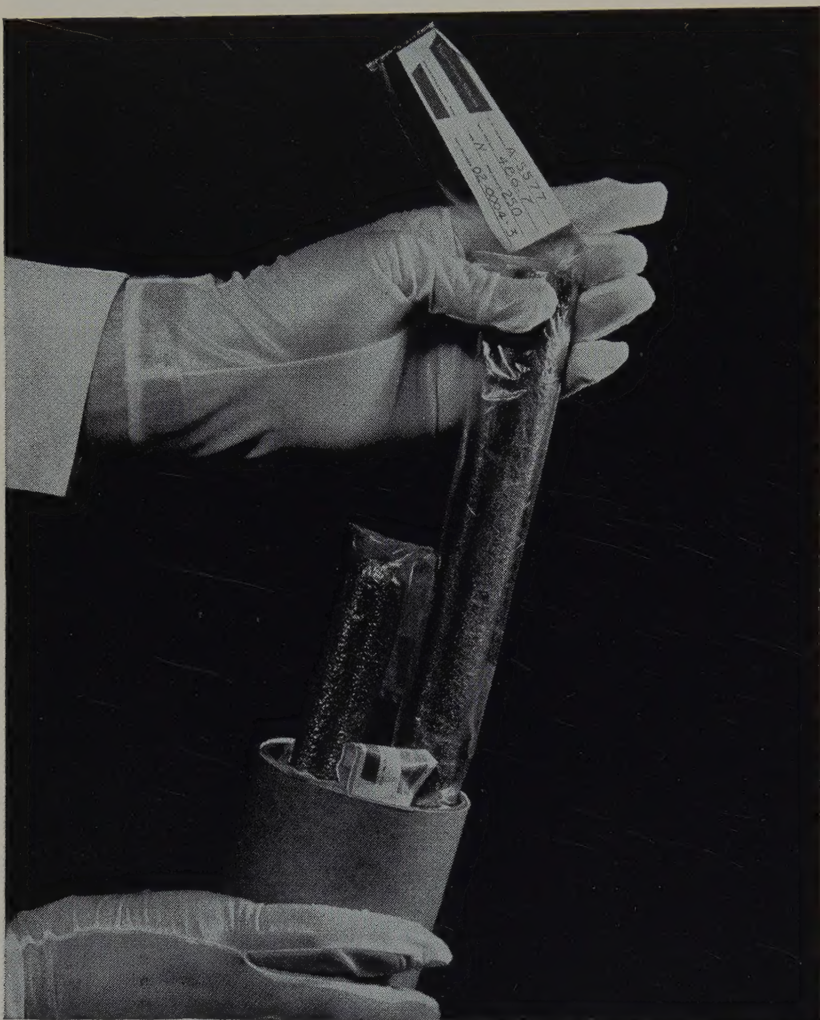
Two new diode packages are being compared with a conventional package by means of an optical comparator. Dr. Edward M. Davis of the Solid-State Device Development group, IBM Data Systems Division, points to a diode mounted in a conventional package. Dr. Davis and his colleague, S. S. Im, are comparing its physical characteristics to the smaller IBM "rivet" and "micro-wedge" packages.

SILICON NEWS from Dow Corning

(PART 1)

# The Untouchables

## Hyper-Pure Silicon . . . Silicon So Pure Just a Touch Contaminates Its Quality



***The highest purity*** attained in any element refined by man . . . purer than any element found in nature! That's Hyper-Pure Silicon.

With less than one part per billion of boron, Dow Corning Silicon is so pure that just the touch of a finger tip causes contamination — destroys its high quality.

To assure this untouchable purity when you receive them, Dow Corning polycrystalline rods are wrapped in special unbleached cellophane and sealed in airtight polyethylene envelopes.

***Purity pays off in quality*** — in uniformity of properties . . . in relatively flat resistivity and lifetime profiles for the entire length of single crystal silicon grown from Dow Corning polycrystalline rod and chunk . . . in maximum yield.

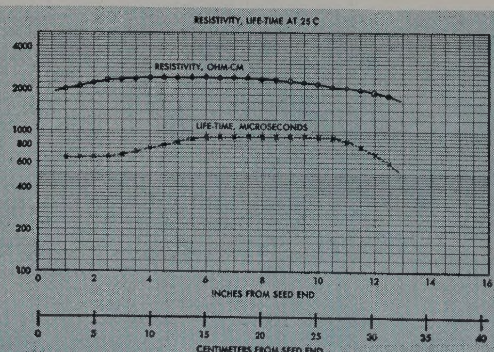
Specify polycrystalline rod if you use the zone refining process for conversion to single crystal — polycrystalline chunk if the Czochralski method is used. Both are of the same high quality.

Why is Dow Corning able to supply this untouchable quality?

Dow Corning has nearly twenty years experience in the production and purification of trichlorosilane, a chemical basic to both *Silicones* and *Hyper-Pure Silicon.* This experience, plus a fully integrated production facility, assures uniformly high quality — minimizes batch to batch variations.

For more information contact our nearest regional office, or write direct.

Typical properties of Dow Corning polycrystalline silicon, together with resistivity and life-time curves for an evaluation crystal, are shown below.




*Typical Properties of Polycrystalline Silicon*

| | |
|---|---|
| Acceptor Impurity Content: | 0.15 part/billion |
| Donor Impurity Content: | 0.5 part/billion |
| Rod Diameter: | up to 26 mm (1.0 in.) |
| Rod Length: | up to 450 mm (17.7 in.) |
| Resistivity (vacuum zoned evaluation crystal): | >1000 ohm cm |
| Lifetime (vacuum zoned evaluation crystal): | >400 micro sec. |

Free brochure — "Hyper-Pure Silicon for Semiconductor Devices." Write Dept. 8212.

HYPER-PURE SILICON DIVISION
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MIDLAND, MICHIGAN

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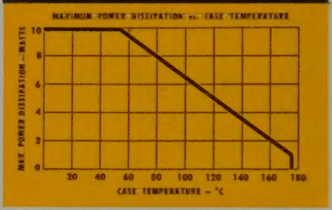
# SHARPEST ZENERS AVAILABLE!

## NOW... GI OFFERS YOU A COMPLETE LINE OF QUALITY ZENER DIODES

## NEW 10-WATT ZENERS...

- *Extremely low Dynamic Impedance*
- *Superior Case Design*
- *Up to 175° C Operation*
- *Diffused Junction Type*
- *100% Scope Tested*


**Outstanding Quality**—New line of superior quality 10-watt zener diodes provides dependable uniformity of electrical characteristics ... *completes* the family of General Instrument zeners. Unique case design, which employs thermal matching of silicon and package, enables units to withstand rapid temperature cycling and thermal shock. Low junction operating temperature means high reliability and long life. Conservatively rated diodes show extreme stability under life tests at maximum parameters.

**New Diodes Available for Immediate Delivery** in Types 1N1808; 1N2044 through 1N2049; and 1N1351 through 1N1362. Voltage ranges from 7.5 to 30 volts (higher upon request).

REPRESENTATIVE GROUP OF SUPERIOR ZENERS FOR YOUR MOST EXACTING CIRCUIT REQUIREMENTS... 10 WATTS TO ¼ WATT

(Standard types supplied ∓ 10% of stated value; ∓ 5% tolerances available except as indicated.)

| New 10-Watt Zeners | | | | 3.5-Watt Stud Mount† | | | | 1-Watt Axial Lead† | | | | ¼-Watt Axial Lead | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type | Zener Voltage (v) | Test Cur. @ 55° C (ma) | Max. Dyn Imp. (ohms) | Type | Zener Voltage (v) | Test Cur. @ 25° C (ma) | Max. Dyn. Imp. (ohms) | Type | Zener Voltage (v) | Test Cur. @ 25° C (ma) | Max. Dyn. Imp. (ohms) | Type | Zener Voltage (v) | Test Cur. @ 25° C (ma) | Max. Dyn Imp. (ohms) |
| 1N1808 | 9.1 | 500 | 1 | 1N1588 | 3.6-4.3 | 150 | 2.6 | 1N1518 | 3.6-4.3 | 50 | 9 | 1N708 | 5.6 | 25 | 3.6 |
| 1N1351 | 10 | 500 | 2 | 1N1589 | 4.3-5.1 | 125 | 2.3 | 1N1519 | 4.3-5.1 | 40 | 8.5 | 1N714 | 10 | 12 | 8 |
| 1N1352 | 11 | 500 | 2 | 1N1590 | 5.1-6.2 | 110 | 1.4 | 1N1520 | 5.1-6.2 | 35 | 5.5 | 1N718 | 15 | 12 | 13 |
| 1N1353 | 12 | 500 | 2 | 1N1591 | 6.2-7.5 | 100 | .58 | 1N1521 | 6.2-7.5 | 30 | 1.6 | 1N721 | 20 | 4 | 20 |
| 1N1355 | 15 | 500 | 2 | 1N1592 | 7.5-9.1 | 80 | .5 | 1N1522 | 7.5-9.1 | 25 | 1.1 | 1N723 | 24 | 4 | 28 |
| 1N1357 | 18 | 150 | 3 | 1N1593 | 9.1-11 | 70 | .7 | 1N1523 | 9.1-11 | 20 | 1.5 | 1N731 | 51 | 4 | 115 |
| 1N1358 | 20 | 150 | 3 | 1N1594 | 11-13 | 50 | 1.4 | 1N1524 | 11-13 | 15 | 2.4 | 1N735* | 75 | 2 | 240 |
| 1N1359 | 22 | 150 | 3 | 1N1595 | 13-16 | 40 | 3.4 | 1N1525 | 13-16 | 13 | 5.4 | 1N738* | 100 | 1 | 400 |
| 1N1360 | 24 | 150 | 3 | 1N1596 | 16-20 | 35 | 6 | 1N1526 | 16-20 | 10 | 11 | 1N742* | 150 | 1 | 860 |
| 1N1361 | 27 | 150 | 3 | 1N1597 | 20-24 | 30 | 9 | 1N1527 | 20-24 | 9 | 18 | 1N744* | 180 | 1 | 1200 |
| 1N1362 | 30 | 150 | 4 | 1N1598 | 24-30 | 25 | 13 | 1N1528 | 24-30 | 7 | 28 | 1N745* | 200 | 1 | 1400 |

*Supplied with ∓ 10% tolerance only.
†Intermediate values supplied with ∓ 5% tolerances on order.

*CONTACT GENERAL INSTRUMENT for full technical information on the complete line of zener diodes, and for applications assistance on all your semiconductor needs.*

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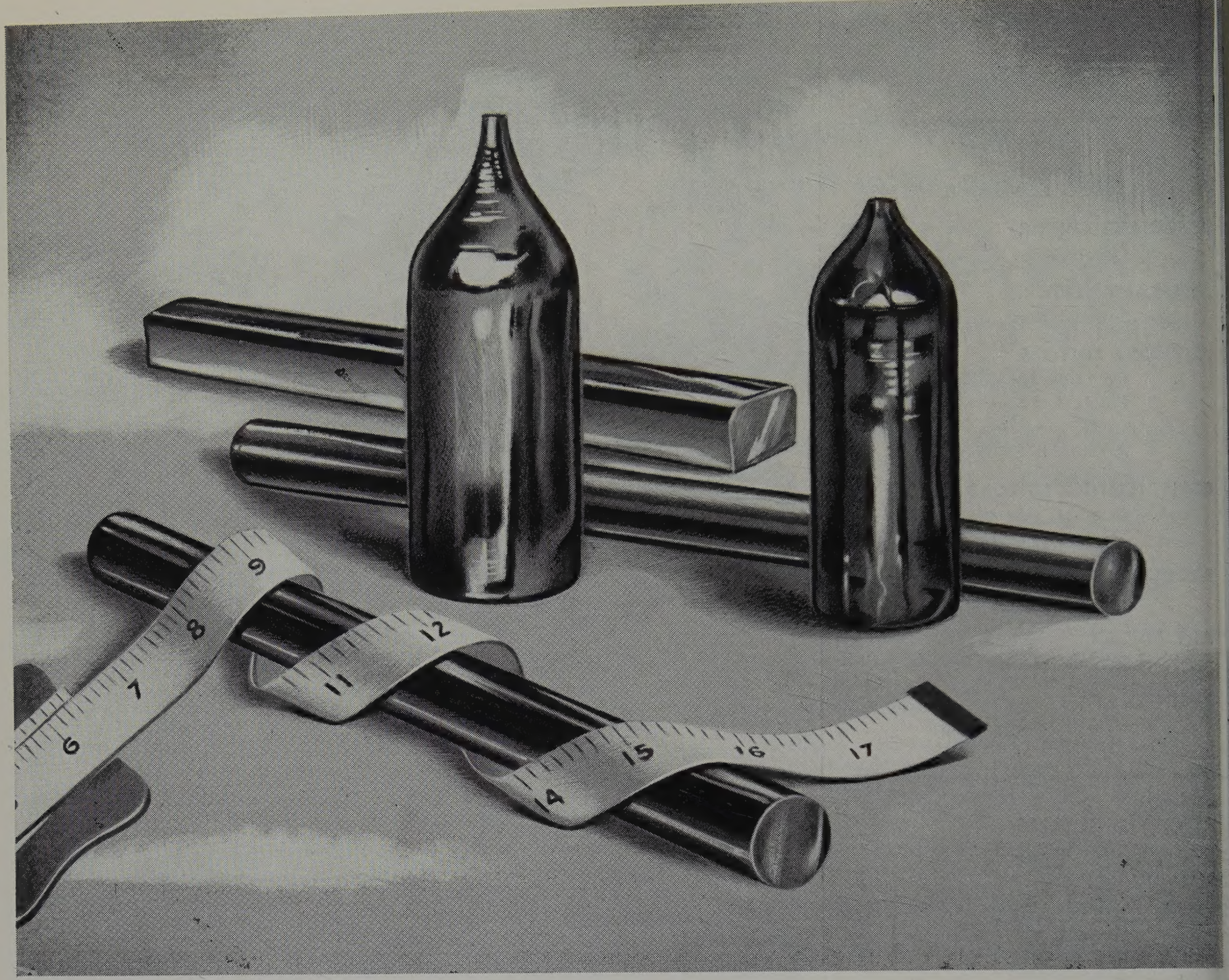

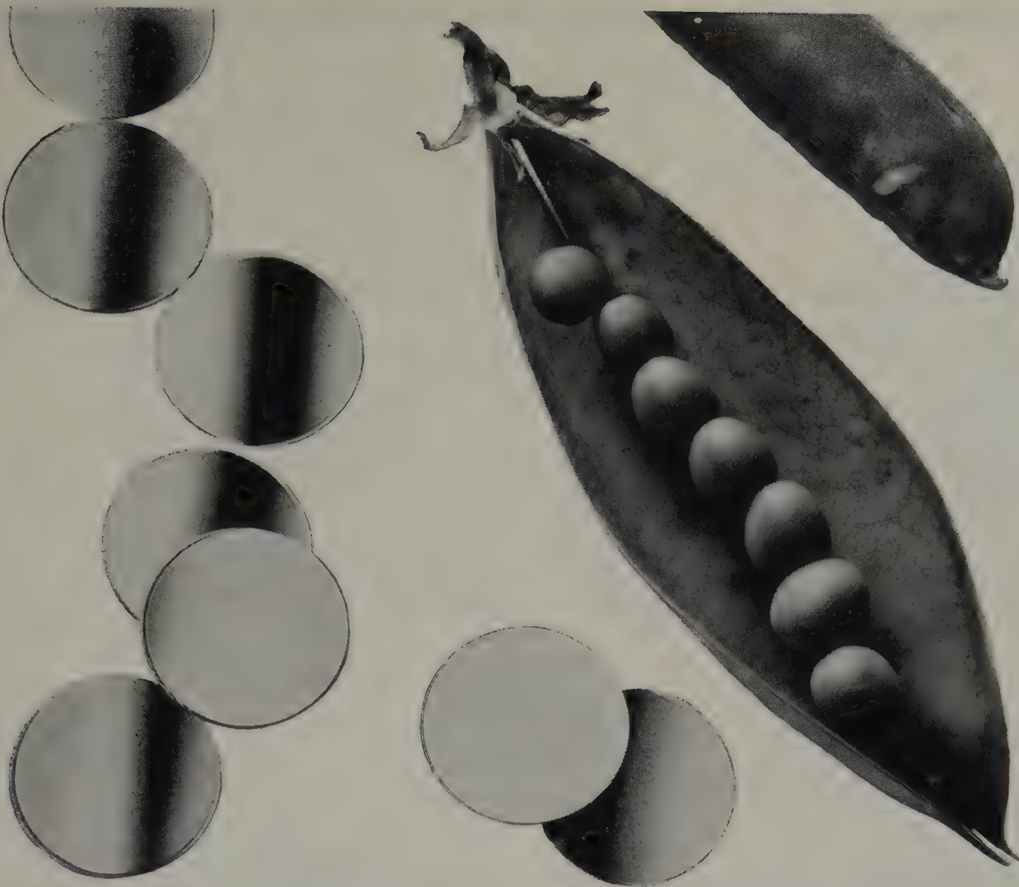

# Peas are Pikers!

They can't start to compare for consistency with silicon produced by Allegheny. Your Allegheny silicon slices or dice, for example, will set new standards of dependable uniformity. Each and every one will meet your specifications exactly because each is individually checked for physical and electrical characteristics before we ship it.

Other forms of Allegheny semiconductor silicon — and we produce them *all* including bulk — can be relied upon to the same degree. They're manufactured by *specialists* whose only business is silicon. Strictly controlled production and 100% testing insure a higher degree of dependability than you've ever enjoyed before. This saves your time and your temper — *raises your production yield dramatically.*

Perhaps, as we have already done for many manufacturers of electronic devices, we can save you from large capital outlays for equipment to process your own single crystals or slices — and the trouble that usually follows when you try. Or, if you already have some of the facilities, we'll supply the bulk silicon, billets, rods, doping alloys, single crystals or special forms and seeds you need — and stand by as your secondary or emergency source for finished slices or dice.

In any case, you can be sure that Allegheny will ship you the silicon you order right to the letter of your specs, that your deliveries will be prompt, and that you can get highly competent technical help if you need it. You can be sure that Allegheny, as *specialists,* can help you cut the time and material wastes you may have had with silicon in the past.

For silicon as you like it — *and as you specify it,* phone, wire or write. (Our TWX number is BRFD 8444.)

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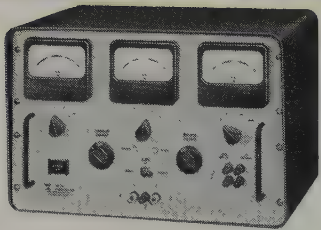
# SEMICONDUCTOR TEST EQUIPMENT

## To Accurately Evaluate Semiconductor Parameters

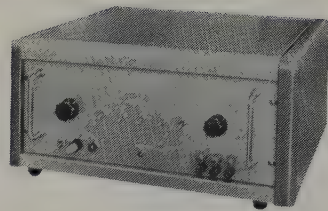
- Incoming Inspection
- Production Test
- Reliability Systems



### 20 AMPERE DYNAMIC RECTIFIER ANALYZER

- Forward current 1/5/20 amp. D.C. full scale
- Reverse voltage 250/1000V. peak
- Forward voltage drop 0-1, 0-5V.
- Reverse current from 1$\mu$a to 50ma. in four ranges
- Self-contained, no external load resistors
- Mirror scale 1% instruments
- Tests under actual operating conditions in accordance with Mil. Specs.

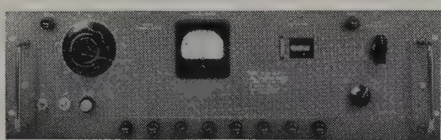
Model 170 Price $855.00 Delivery: Stock-2 Weeks



### 75 AMPERE SURGE TEST ADAPTER

- Provides surge current test for silicon rectifiers in accordance with Mil. Specs.
- Continually adjustable to 75 amp. peak
- Self-contained, portable
- Single half wave sinusoidal pulse
- 660, 2500 and 6000 amp. units available
- 1% monitoring accuracy
- Automatic programming available

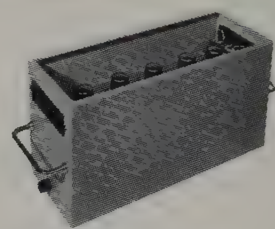
Model 142 Price $725.00 Delivery: Stock-2 Weeks



### MODULAR DYNAMIC TEST POWER SUPPLY

- Simulator circuit
- Forward current & reverse voltage adjusted independently
- Reduces operating costs by a factor of 50
- Capacity is 20 rectifiers 0.1 to 1 amp. or any combination up to 2 rectifiers, 10 amp. each
- Mirror scale 1% instruments

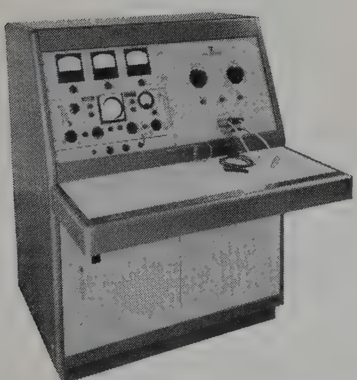
Model 154D Price $800.00 Delivery: 2 Weeks



### LIFE TEST MODULE

- Self-contained switching module
- Simulator circuit
- Units may be set up in parallel for testing above 10 amp.
- Reduces operating costs by a factor of 50
- Plug-in rack adapters available for 3, 4, and 5 modules
- Forward drop equalizing resistors

Model 180A Price $250.00 Delivery: Stock-2 Weeks



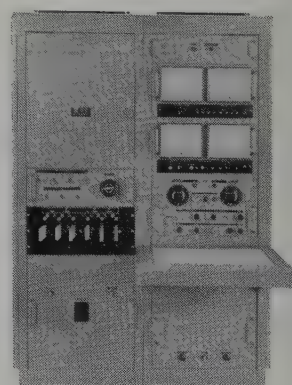
### THERMAL RESISTANCE TEST INSTRUMENT

- Measures junction temperature
- Accuracy within 5% (under standard conditions)
- Heating current 1-5, 1-50 amps.
- Measuring current 1-100ma.
- 1% instruments
- Measuring pulse 100$\mu$ sec.
- Scope display included

Model 149 (Basic Unit) Price $6200.00 Delivery 6 Weeks
Lower power units available

### 200 AMPERE DYNAMIC TEST SET

- Forward current 20/200 amp. D.C. full scale
- Reverse voltage 0/1500V. peak
- Forward voltage drop 0-5/10V. peak
- Reverse current from 2 $\mu$a to 250ma. in four ranges
- Self-contained, no external load resistors
- Mirror scale 1% instruments
- Tests under actual operating conditions in accordance with Mil. Specs.



Model 164 (Basic Unit) Price $11,525.00 Delivery 8-10 Weeks

*Complete Reliability Evaluation Systems Available*

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*Manufacturers of Semiconductor Test Equipment*

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# Personnel Notes

General Instrument Corporation named Dr. Robert W. Hull as Vice President in Charge of Reliability of its recently expanded Semiconductor Division.

Thomas S. Hurley has been named to the new post of supervisor of merchandising and advertising for CBS Electronics semiconductor operations.

Herbert S. Evander has been appointed manager of transistor sales for the semiconductor division of Hughes Aircraft Company, it was announced recently by Robert B. Harlan, Jr., div. marketing mgr.

Appointment of Dr. Michael Mejac, chemical engineer, formerly of Milwaukee, Wisconsin, to the research and development department of Rheem Semiconductor Corporation at Mountain View, Calif., was announced recently.

Eugene A. Fischer has been appointed sales manager of refractories by Norton International Inc. Gale W. Bennett has been named assistant manager of product engineering in the Refractories Division.

Charles E. Sporck has been appointed Transistor Plant Manager for Fairchild Semiconductor Corporation in Mountain View, California.

John Spitzer has joined the Semiconductor Division of Sylvania as supervisor of advertising and sales promotion, it has been announced by David B. Tolins, Jr., manager of advertising and merchandising for the division.

Standard Rectifier Corporation recently announced the promotion of Neil A. De Fazio to general sales manager. Former industrial sales manager for SRC, he fills the post recently vacated by James R. Conto.

The appointment of Robert S. Ames to the position of General Manager of Sonobond was recently announced.

Ralph T. Dosher, Jr. has been appointed Manager of the Automation Products department of Texas Instruments Incorporated Geosciences & Instrumentation division's Instrumentation group at Houston, C. W. Nimitz, Jr., Group Manager, announces.

Appointment of Robert L. Dietrichson as West Coast Regional Manager of Veeco Vacuum Corp., was announced recently by William R. Meoli, vice president.

Robert M. Palmer was recently named Field Sales Manager of Hevi-Duty Electric Company, Milwaukee manufacturers of Industrial Heat Processing Equipment.

G. William DeSousa, Marketing Manager of Sperry Semiconductor Division, Sperry Rand Corporation, recently announced the appointment of Edwin P. Berlin as Advertising Manager.

Dr. A. I. Mlavsky has joined the TYCO Materials Research Laboratory as manager of the energy conversion department, according to Dr. A. J. Rosenberg, director of the laboratory.

The appointment of Jerome Berger as sales manager of the Contract and Special Products Division of JFD Electronics Corp., Brooklyn, N.Y., was announced.

# Book Reviews

**TITLE:** Millimicrosecond Pulse Techniques

**AUTHORS:** I. A. D. Lewis and F. H. Wells

**PUBLISHER:** Pergamon Press, New York, London

*Millimicrosecond Pulse Techniques* is Volume VI of a series entitled "International Series of Monographs on Electronics and Instrumentation" published originally in Great Britain.

The first three chapters of the book review basic theory of electronics and introduce some terminology utilized by electronic circuit engineers. The first chapter is a theoretical introduction and covers briefly the mathematical interpretation of the pulse. The second chapter discusses transmission lines and the properties of filters. The third chapter applies much of the material of the previous two in a discussion of transformers and impedance matching. This chapter also brings out the concept of delay lines in addition to several other useful topics.

The fourth chapter deals with the generation of pulses. Various electronic and electro-mechanical methods of pulse generation are presented such as the discharge line and coaxial relay pulser as typical examples. Practical circuits of these, and more sophisticated systems, are delineated and many vacuum tube circuits are described together with methods of measurement and amplitude attenuation.

The fifth and sixth chapters cover Amplifiers and Cathode Ray Oscilloscopes respectively. Here may be found complete discussions of distributed amplifiers, peaking and gain stabilization, in addition to a very thorough and interesting discussion of the oscilloscope. Many practical circuits are given and the material is well referenced.

The balance of the book (chapters VII and VIII) are devoted to applications of the circuit techniques to other fields. Chapter VII is a discussion of the use of pulse methods in nuclear physics and gives many circuits and systems for particle counters. The use of transistors is briefly covered in chapter VIII. The book concludes with an appendix, an index and a very thorough list of references for additional material.

*Millimicrosecond Pulse Techniques* is an excellent, fairly concise book dealing with pulse electronics. Although the book does not place sufficient emphasis on transistor circuitry, there are many basic concepts well defined making the book useful as a preliminary source of information for the pulse circuit designer.

**TITLE: Digital Computer Primer**

**AUTHOR:** E. M. McCormick

**PUBLISHER:** McGraw-Hill

The *Digital Computer Primer* is a book written to present and explain the operation of automatic digital computers to the uninitiated engineer. Indeed, it is the author's stated intention to present the computer in a manner understandable to the "well informed" layman. In both cases the book aptly succeeds.

The first chapter, a general introduction, develops the difference between a computer and a calculator. This is followed by two chapters devoted to the organization of computers and elementary coding. These chapters stress the four major units of a computer, namely, the authentic unit, the storage unit, the control unit and the input-output unit and the methods by which a computer solves problems. Several programming examples for the solution of compound interest problems serve to illustrate the point. Square-root computation and sorting programs are also considered as examples.

Chapter 4, entitled "Number Systems" is a remarkably well-presented introduction to binary notation, the language of modern computers. A great deal of material on binary arithmetic operations and binary-coded decimal systems is covered.

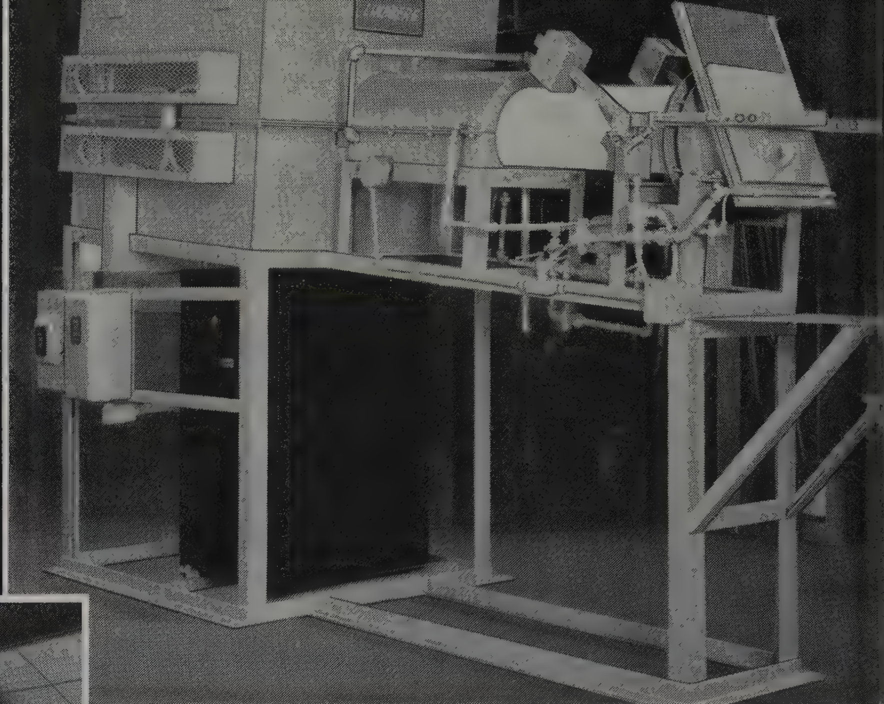
Chapters 5, 6 and 7 develop the logic of computers, methods of control and logical units. Here the basics of the computer are explained. The various gates such as the AND, OR and INHIBIT are covered as well as other blocks and control devices. Binary addition is treated in detail as well as decimal addition and the logical operations of the half and full adder.

Many additional topics are treated in the remainder of the book. Chapter 8 discusses storage methods in surprising detail. Chapter 9 explains input-output systems. Chapter 11 outlines methods of checking. The book concludes with two appendices devoted to mathematics of logic and word distribution.

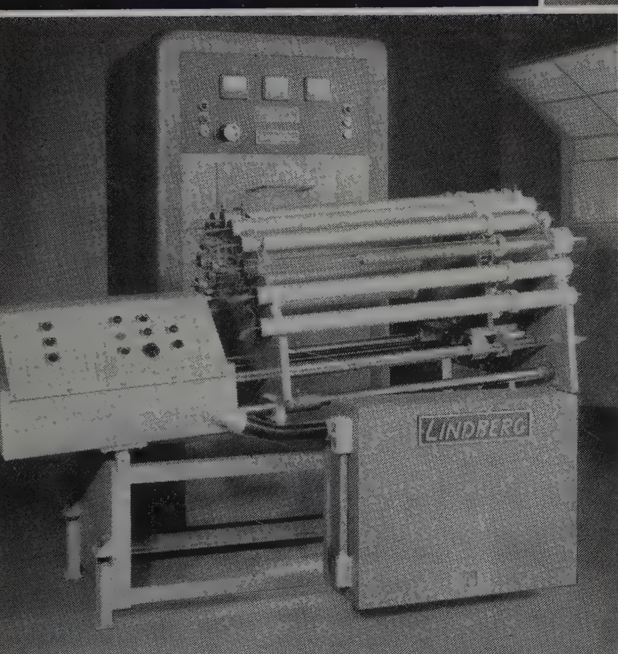
*Digital Computer Primer* is an exceptionally fine book and is one of a series on information processing and computers. Author McCormick approaches his topic in readily understandable terms making his book highly readable and recommended for all those interested in a basic understanding of digital computers.

*By Stephen E. Lipsky*

# Wherever heat is needed for electronics research or production Lindberg equipment can provide it



This Lindberg Hydrogen Atmosphere Furnace is designed for the reduction of german oxides and other materials. Model illustrated is a hand pusher type but this furnac also available for continuous, automated operation.




Newly-designed Lindberg Horizontal Zone Scanner provides zone purification of metallic germanium and other metallic and organic materials. Lindberg can also furnish Floating Zone Scanners for the purification of silicon.

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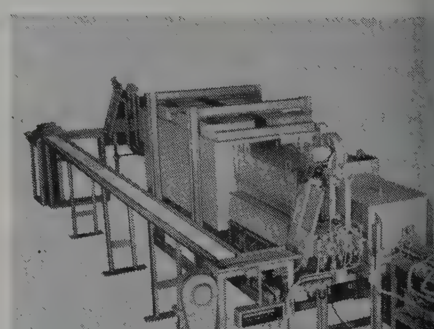

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Vext, using a bit of sandpaper, try removing the solder ating... Observe that coating and base have not sepa- ed during the heating operation. The reason? Alpha's ntinuous Conductive Coating process insures a *perma- nt, metallurgical bond* between the solder and base metal! As a result, for the first time, it is possible to produce ited strip with the following unique advantages:

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2. **These coatings can be added** to the base metal's *entire* surface or just a *part* of it. This latter feature frees one or both ends of the tab for welding to the base lead without the danger of solder splatter!
3. **The base metal** can be supplied in all tempers.
4. **A large variety of alloys** containing n or p type dopants can be applied to a wide range of base materials.

Another advantage of this process is that it produces a uniform coating thickness. This is an important feature in safeguarding alignment of the dice on the base tabs, low electrical resistance and reliable mechanical stability. As a result, you enjoy better in-process control of base tab soldering; *positive ohmic contact is assured!*

See if you don't agree that Alpha coated strip can cut your semiconductor device costs. Make the match test. Write for samples of Alpha coated strip. We'll also send you free Alpha Technical Bulletin No. 107, "Alloy Coated Metals." Act now!

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# Editorial . . .

## Tunnel Diode Integrated Circuitry

One of the most dramatic aspects of the solid state art is represented by the improvements in operational efficiency and in reduced size that may be achieved in system designs. As the components technology improves there is a continuous tendency to realizations with smaller and smaller dimensions, consistent with the requirements of power dissipation, reliability, frequency of operaton and cost.

Often the designer finds that the connecting leads occupy as much space as the components and as a natural result attempts to integrate the latter in one block only. Due to difficulties in the realization of high Q inductors, such designs are generally limited to systems consisting of *p-n* junctions, resistors and capacitors. The tunnel diode seems particularly appropriate for such types of applications because in the absence of external connecting leads, its parasitic elements (lead inductance and spread resistance) may be more easily reduced and controlled. Furthermore, the unit lends itself to compact designs with a minimum of components.

An interesting discussion of the present and future design trends has been given by M. E. Hines (*B.S.T.J., May 1960*) with reference to applications to lumped and distributed parameters useful for oscillation or amplification. For comparison of design criteria one considers the maximum frequency for negative resistance effects, the maximum power handling capacity, the convenience of power feed. If $R_s$ is the spreading resistance and $R_n$, $C$ are respectively the negative resistance and the capacitance, the latter frequency is approximately

$$f_{max} = \sqrt{\frac{R_n}{R_s}} \Big/ 2\pi R_n C.$$

In this relation only $R_s$ depends on the junction geometry and therefore represents a parameter of direct interest. For example, if single spot diodes are compared with distributed structures consisting of strip diodes, it is found that the former have higher $f_{max}$. On the other hand, the comparison on the basis of the power handling capacity is not as favorable.

It is relatively easy to build tunnel junctions in an integral block with their resonant elements. Several elegant solutions have been devised which involve cylindrical cavities or transmission lines. Due to the fact that the operation of the diode requires rather low values of load impedance, the unit must be inserted at low impedance points, such as for example at the base of a cylindrical cavity or near the terminations of a half-wave transmission line. One may also devise a parallel plate transmission line in which the two conductors form the distributed *p* and *n* regions of the tunnel junction structure. If high frequency operation is desired, it is essential to make recourse to very low junction capacitances and for this reason distributed structures consisting of a very thin strip line diode placed along the center line of a metallic strip line of appreciable width are more convenient. The latter design is also attractive because its characteristic impedance is reasonably large, thereby facilitating the problems of power feed.

The stability of operation demands the use of appropriate nonreciprocal elements in the amplifier system. For example, hybrid junctions with two negative resistances may be used to provide cancellation of the reflected waves at one frequency. On the other hand ferrite slabs with nonreciprocal attenuation may be integrated with the distributed structures without difficulty.

Although the construction of tunnel diodes has made great progress, still further advances will probably occur through the discovery of better methods of obtaining negative resistance effects useful for the microwave and millimeter wave range.

# A Tunnel Diode Monostable Multivibrator

CARL DAVID TODD*

**The tunnel diode is a new device available to the design engineer. Proper application of the tunnel diode demands an approach radically different than is used with vacuum tubes or transistors. This article discusses the tunnel diode as applied in a monostable multivibrator circuit. A mathematical design analysis is presented along with a study of the effects of temperature and supply voltage variation. Triggering requirements are discussed as are the effects of circuit loading.**

THE TUNNEL DIODE as announced by Esaki[1,2] and discussed in recent papers and articles[3,4,5] is a single *p-n* junction diode which displays a negative resistance region in its forward biased characteristic curve. The tunneling mechanism by which the device operates occurs at the speed of light, thus allowing switching speeds much greater than that for transistors or any of the commonly available negative resistance devices.

Tunnel diodes operate at voltage levels much lower than those of other devices which the design engineer is accustomed to using. This means that new techniques will have to be developed to make full use of these devices. It may even be necessary to develop other components to fully complement the tunnel diode in some applications.

One application of the tunnel diode is in a monostable multivibrator circuit. It is with this application that this article is primarily concerned. A simplified analysis of the circuit will be presented along with specific design procedures, laboratory experimental results, and some practical uses.

## Negative Resistance

Many electronic circuits and devices exhibit a negative resistance; that is, at least a portion of the voltage-current characteristic displays a decreasing current for an increasing voltage or a decreasing voltage for an increasing current. It is customary to divide the negative resistance devices and circuits into two major classes referred to as "N"-type and "S"-type.

While the material to be presented in this section is applicable to either devices or circuits exhibiting negative resistance, only devices will be referred to in a direct manner.

The N-type of negative resistance device has the characteristic shape of the curve shown in *Fig. 1.* Note that for a range of voltage values between a peak voltage, $V_P$, and a valley voltage, $V_V$, three current values are possible for each value of applied voltage. If the current is specified, however, only one voltage may exist for that current. N-type characteristic devices are therefore referred to as being current stable or open circuit stable.

Some typical devices which have an N-type characteristic are the gaseous discharge tube, the common base configuration of the point contact transistor using the emitter-base terminals, the silicon unijunction transistor, and the *pnpn* switch.

The S-type negative resistance device exhibits a characteristic curve similar to that shown in *Fig. 2.*

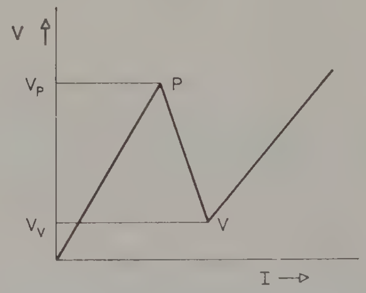


**Fig. 1—Voltage-current characteristic curve of an N-type negative resistance device.**

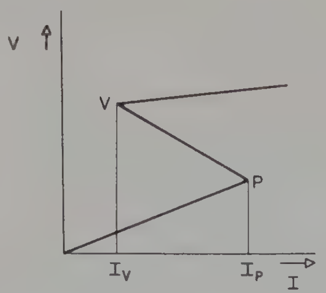


**Fig. 2—Voltage-current characteristic curve of an S-type negative resistance device.**

* Advanced Application Section; Hughes Semiconductor Div., Hughes Aircraft Co., Newport Beach, Calif.

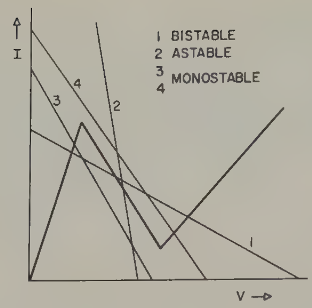


**Fig. 3—Biasing methods determine mode of operation.**

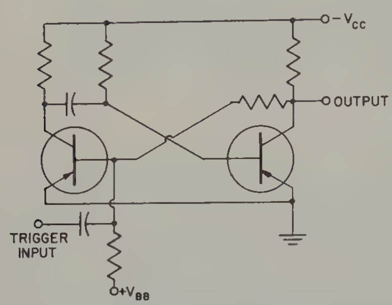


**Fig. 4—A junction transistor monostable multivibrator.**

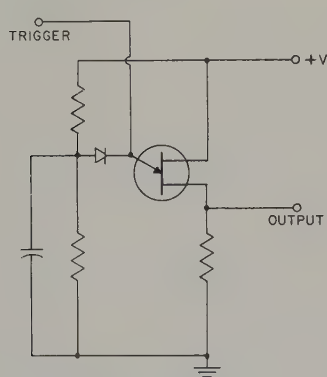


**Fig. 5—Basic circuit for a monostable multivibrator using the silicon unijunction transistor.**

Note that for this device, there is a range of current values between a valley current, $I_V$, and a peak current, $I_P$, for which three voltage values may exist. Specifying the voltage, however, defines the one and only one value of current which may exist. S-type negative resistance devices are therefore referred to as being voltage stable or short circuit stable.

Typical devices having an S-type characteristic are the vacuum tube tetrode (as used in the dynatron oscillator), the point contact transistor in the common emitter configuration using the base-emitter terminals, and now the tunnel diode.

N-type and S-type negative resistance devices are duals of each other and therefore the theorems of duality are useful in transferring the knowledge of operation or design procedure from one type of device to another. This is helpful since most engineers have had more experience in working with device having an N-type characteristic than with S-typ negative resistance devices such as the tunnel diode.

By proper choice of the manner in which the nega tive resistance device is biased, operation may b obtained which is bistable, astable, or monostable a shown in *Fig. 3*. For bistable operation, it is necessar that the load line intersect the operating character istic curve at two stable points as in the case of loa line 1 of Fig. 3. Normally, this means that the loa line will intersect the characteristic curve at thre points, two of which are in the positive resistanc regions and one point which is in the negative resist ance region.

Astable operation is assumed if the load line inter sects the characteristic curve at only one point an this point must be within the region of negative re sistance as for load line 2 of *Fig. 3*.

Monostable operation occurs when the load lin intersects the characteristic curve at only one poin in one of the positive resistance regions as for loa lines 3 and 4 of *Fig. 3*.

In all three cases trigger power is applied to shif the load line momentarily thus causing switchin action. Methods of trigger application and the result ing switching behavior will not be discussed her except for the monostable condition.

## Basic Monostable Circuits

Basic monostable multivibrator circuits using junc tion transistors, the silicon unijunction transistor, th four layer diode and the tunnel diode are shown i *Figs. 4, 5, 6* and 7 respectively.

The circuit shown in *Fig. 4* for the junction tran sistor requires two transistors, five resistors, and tw capacitors for a total of nine components.

The circuit of *Fig. 5* for the silicon unijunctio transistor is considerably simpler in nature having total of only six components.

For the four layer diode, the circuit is even simple as shown in *Fig. 6*. The appearance of the tunne diode monostable circuit of *Fig. 7* is of the sam order of complexity as that for the four layer diode

The speed of the tunnel diode is much faster tha that of the other devices and environmental effect should be considerably less. Projected cost figure indicate that the single tunnel diode will be much cheaper in the future than the other elements, espe cially the two junction transistors if high speed i needed. It should be kept in mind that the amplitud and nature of the outputs are very different for a the types of circuits illustrated.

## Analysis

As previously mentioned, in order to obtain mono stable operation, it is necessary that the load lin intersect the characteristic curve at only one poin which lies within one of the positive resistance re gions. The conditions indicated in *Fig. 8* satisfy thi

requirement. It is also necessary to have some form of energy storage element for proper action. This will become more apparent in the discussion to follow.

At rest, the operating point is at point "a" of *Fig. 8*. The tunnel diode is conducting heavily and the voltage drop across it will be in the order of 40 millivolts. Now if a positive voltage, $V_T$ is presented to the input terminal of the circuit of *Fig. 7*, the current will increase slightly. If the total current through the tunnel diode reaches and attempts to exceed the value of $I_P$, then a switching action will occur and the operating point will very quickly move to point "b*". The inductance $L$ maintains the current $I_a$ since the current through an inductor may not change instantaneously. Under most situations, the switching action occurs before the trigger can be removed thus causing the value of the current at point "b*" to be the sum of $I_a$ supplied by the inductor and some remaining trigger current (assuming that the trigger input voltage, $V_T$, is greater than $V_b$). As soon as the trigger current is removed, the operating point will shift to point 'b".

As the energy stored in the inductor, $L$, begins to be dissipated, the current will begin to fall at a rate determined by the time constant of the circuit until operating point "c" is reached. If the current through the tunnel diode drops below the valley current, $I_V$, which is equal to $I_c$, switching action again occurs—this time from point "c" to point "d". Since point "d" is not a stable operating point for steady-state conditions, the current must then start to increase at a rate again determined by the time constant of the circuit. As will be shown later, this time constant is not the same as that present during the transition from point "b" to point "c". When the tunnel diode current reaches point "a", the cycle is completed and the circuit is ready to receive the next input trigger current pulse.

The time required to switch the tunnel diode from point "a" to point "a*" and then to point "b*" will be negligible for most cases since the tunneling mechanism is very fast if we neglect capacitative effects.

At the instant after the transition from operating point "a*" to point "b*", it is assumed in this analysis that the trigger current is removed, thus allowing almost immediate progression to point "b". It may be shown that if the trigger current is removed before the transition to point "c" is complete, the effect is the same as if it had occurred at the assumed time.

As operating point "b" is reached, the equivalent circuit is as shown in *Fig. 9*. The tunnel diode has been momentarily represented as a voltage source in series with a resistance $R_{bc}$ and the series combination shunted by a capacitance, $C_s$. $R_{bc}$ is the slope of the characteristic curve between points "b" and "c*". If the slope were allowed to extend as shown in *Fig. 8*, the slope would intersect the zero current axis at a voltage equal to $V_2$. This representation is valid over a range of current and will be used in order to obtain a mathematical analysis of the time required for the transition from point "b" to point "c". For the present the effect of $C_s$ will be neglected thus simplifying the analysis considerably.

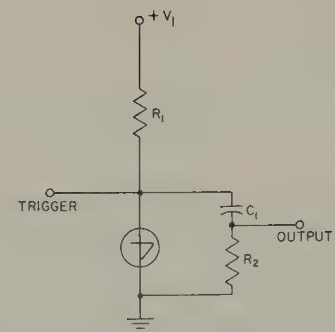


**Fig. 6—Basic circuit for a monostable multivibrator using the four-layer diode.**

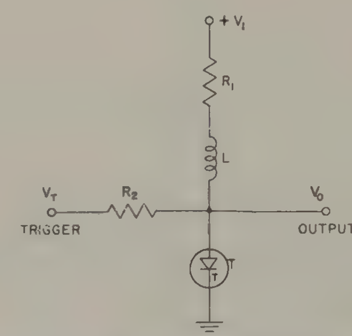


**Fig. 7—The tunnel diode monostable circuit.**

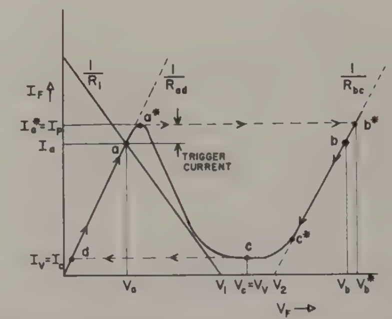


**Fig. 8—Operation of the tunnel diode monostable circuit.**

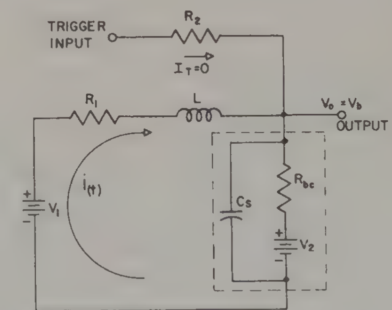


**Fig. 9—Equivalent circuit at the instant operating point "b" is reached.**

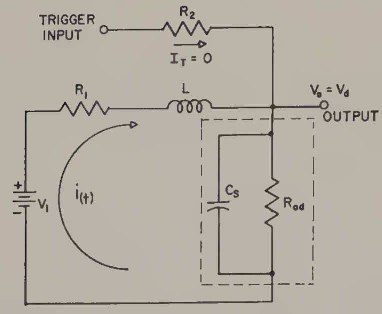


**Fig. 10—Equivalent circuit at the instant operating point "d" is reached.**

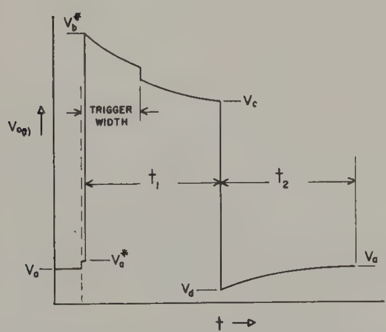


**Fig. 11—Output waveform of the tunnel diode monostable circuit.**

The equation describing the current, $i_{(t)}$, flowing in the circuit of *Fig. 9* may be written and solved for the time, $t_1$, required for the transition from point "b" to point "c". If it is assumed that the indicated slope is followed until $i_{(t)}$ is equal to $I_V$, then the time required is:

$$t_1 = \frac{L}{R_1 + R_{bc}} \ln \left[ \frac{I_a + \dfrac{V_2 - V_1}{R_1 + R_{bc}}}{I_V + \dfrac{V_2 - V_1}{R_1 + R_{bc}}} \right]$$

The time required for the transition from point "c" to point "d" may be assumed to be negligible as was done previously for the transition from point "a*" to "b*".

For the final transition from point "d" to point "a" the equivalent circuit shown in *Fig. 10* is valid. The tunnel diode may be represented by a single resistor $R_{ad}$ (given by the inverse slope of the characteristic curve as shown in *Fig. 8*) shunted by a capacitor. No voltage source is needed since the curve passes through the origin. As before, the effect of the capacitor will be neglected.

The equation for the current, $i_{(t)}$ flowing in the circuit of *Fig. 10* may be written and solved for the time, $t_2$, required to go from point "d" to point "a":

$$t_2 = \frac{L}{R_1 + R_{ad}} \ln \left[ \frac{I_V - \dfrac{V_1}{R_1 + R_{ad}}}{I_a - \dfrac{V_1}{R_1 + R_{ad}}} \right]$$

The resulting waveform at the output will be that of *Fig. 11*. The time, $t_1$, is of primary interest as the pulse width. Time $t_2$ is the additional time for full recovery. Thus the maximum repetition rate may be approximated by the expression:

$$f_{max} = \frac{1}{t_1 + t_2}$$

It is of interest to determine the effect which supply voltage variation has upon value of the time $t_1$, starting with the equation for the time as given previously. For a given condition $I_a$ will vary as $V_1$ varies according to the relationship:

$$I_a = \frac{V_1}{R_1 + R_{ad}}$$

Inserting this value in the equation for $t_1$ and performing the partial differentiation with respect to $V_1$ will give the change in $t_1$ per volt change in $V_1$. In order to determine the per cent change, it is only necessary to divide by the original time which can be designated $t_{1o}$. Simplifying this expression gives:

$$\theta = \frac{1}{[(R_1 + R_{ad})\, I_V + V_2 - V_1] \ln \left[ \dfrac{I_a + \dfrac{V_2 - V_1}{R_1 + R_{bc}}}{I_V + \dfrac{V_2 - V_1}{R_1 + R_{bc}}} \right]}$$

The value $\theta$ is then the per cent change in the time $t_1$ per volt change in $V_1$. Most tunnel diodes available today have the general shape of *Fig. 8*. This means that $V_2$ will be greater than $V_1$ and $t_1$ will increase for an increasing supply voltage.

There is a value of load resistance for which a minimum value of $\theta$ exists. Deriving the general expression for the optimum value of $R_1$ is a monumenal task if not an impossible one. A quantitative result will be given later.

### Loading Effects

In the preceeding analysis, it was assumed that no loading existed and that the value of $R_2$ was high enough such that it could be neglected. The effects of loading by an external load resistor and by $R_2$ can be taken into consideration in the design. The tunnel diode may be assumed to possess these loads internally and the various diode parameters modified to include them. The composite characteristic may be obtained either by a graphical approach or by including the shunt resistances when the characteristic curve is plotted.

The analysis may also be modified by a series of approximate mathematical relations:

$$R'_{ad} = \frac{R_L\, R_{ad}}{R_L + R_{ad}}$$

$$R'_{bc} = \frac{R_L\, R_{bc}}{R_L + R_{bc}}$$

$$V'_2 = V_2\left(\frac{R_L}{R_L + R_{bc}}\right) = V_2\left(1 - \frac{R_{bc}}{R_L}\right)$$

$$I'_P = I_P + V_P/R_L$$

Where $R'_{ad}$, $R'_{bc}$, and $V'_2$ represent the composite values.

### Trigger Requirements

Neglecting any diode capacitance, the only requirement for triggering is that $I_T$ be greater than the difference between $I_a$ and $I_a$* of *Fig. 8*. The required voltage is thus:

$$\begin{aligned} V_T &= R_2\, I_T + V_{a*} \\ &= R_2\,(I_{a*} - I_a) + V_{a*} \\ \text{or } &= R_2\,(I_P - I_a) + V_P \end{aligned}$$

For very narrow trigger pulse widths, the diode capacitance must be considered. The equivalent circuit is approximately as shown in *Fig. 10*, except the current through the inductor, $L$, is $I_a$ and the trigger current is not zero. The pulse width must be of sufficient length to allow the voltage across $C_s$ to change from $V_a$ to $V_a$*. Thus, if the trigger voltage is increased, the pulse width may be reduced.

### Design Procedure

For the usual case, the given requirement is to produce a pulse of width $t_1$ from a trigger pulse current $I_I$, and using a tunnel diode with certain known characteristics. It will be assumed that the voltage current characteristic curve is available.

From the characteristic curve of the diode, it is necessary first to determine the values of the two inverse slopes $R_{ad}$ and $R_{bc}$. Both of these values must be graphic approximations since the characteristic curve is not a straight line, but has some curvature in all parts.

The next step is to determine the point where the slope $R_{bc}$ would intersect the zero current axis if it were allowed to extend. This gives the value of $V_2$ used in the various equations.

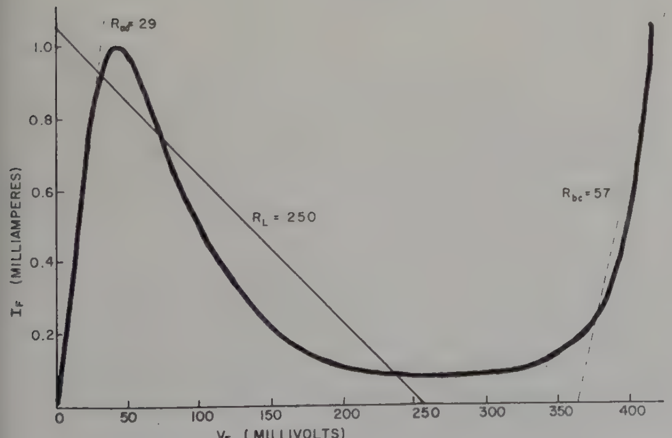


**Fig. 12—Characteristic curve for the tunnel diode used in the design example.**

It is now necessary to decide upon an operating bias current, $I_a$. This will be dependent upon the peak current of the diode and the minimum trigger current available according to the inequalities:

$$I_P > I_a > (I_P - I_T)$$

Next, the load resistance $R_1$ must be chosen such that the load line intersects the characteristic curve at point "a" without intersecting the positive resistance region beyond the valley point. The load line may intersect the negative resistance twice without affecting the operation of the circuit. An approximate value of $R_1$ is given by:

$$R_1 \cong \frac{V_V - V_P}{I_P - I_V}$$

Once $R_1$ is chosen, then the value of the supply voltage may be computed.

$$V_1 = I_a\, R_1 + V_a$$

The required value of the inductor $L$ may now be computed from the equation derived from that given for $t_1$ earlier.

$$L = \frac{t_1\,(R_1 + R_{bc})}{\ln\left[\dfrac{I_a + \dfrac{V_2 - V_1}{R_1 + R_{bc}}}{I_V + \dfrac{V_2 - V_1}{R_1 + R_{bc}}}\right]}$$

The physical value of $R_1$ will be the value previously chosen less the sum of the *dc* resistance of the inductor and the supply resistance.

Sensitivity to supply voltage changes may be checked by use of the equation for $\theta$ given earlier.

This gives the per cent change divided by 100 in the time $t_1$ per volt change in the supply voltage $V_1$.

For a practical example, assume that a pulse width of 10 microseconds is desired from a 150 microampere trigger and using a tunnel diode whose characteristic is given in *Fig. 12*.

Following the procedure previously given, $R_{ad}$ is 29 ohms, $R_{bc}$ is 57 ohms, and $V_2$ is 362 millivolts.

The bias current $I_a$ must be less than 1.0 milliampere and greater than 0.85 milliampere (peak current of 1 milliampere less the trigger current of 150 microamperes). A value of 0.9 milliampere is a reasonable choice for $I_a$.

The value of $R_1$ is then calculated to be approximately 250 ohms. $V_1$ in turn, is equal to 225 millivolts.

Computing the required value of $L$ from its equation we obtain a value equal to 2.8 millihenry.

To see what effect variation of $V_1$ has on $t_1$, the value of $\theta$ may be computed. For this example, the value obtained is 710 percent per volt or 0.71 percent per millivolt.

Several values of $R_1$ may be tried to obtain that value which produces maximum stability. The curve of *Fig. 13* shows the result obtained. While the value of 250 ohms chosen for $R_1$ does not produce optimum

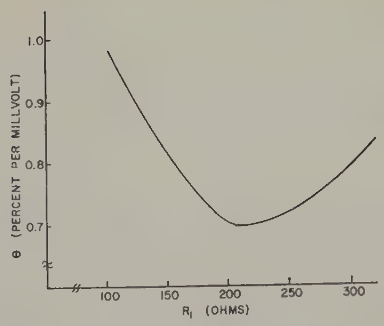


**Fig. 13—Supply voltage sensitivity as a function of $R_1$.**

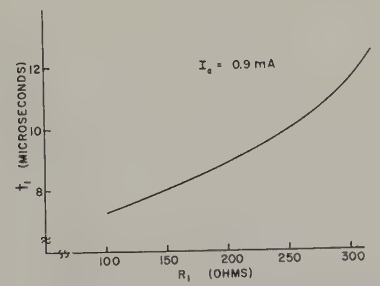


**Fig. 14—Effect of $R_1$ on the pulse width, $t_1$**

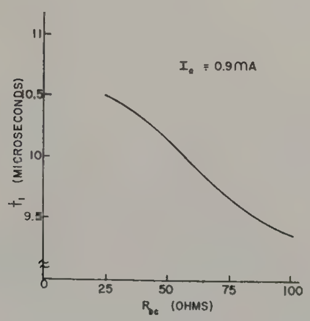


**Fig. 15—Effect of $R_{bc}$ on the pulse width, $t_1$.**

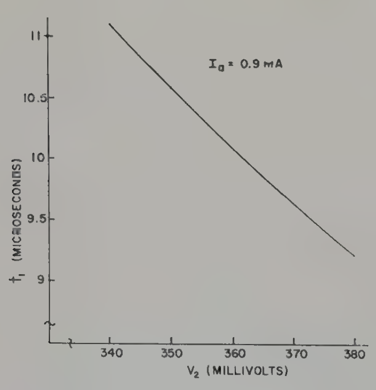


**Fig. 16—Effect of $V_2$ on the pulse width, $t_1$.**

stability, it is close enough. The larger value of $R_1$ also means a smaller inductor may be used than would be necessary with an $R_1$ of 200 ohms as will be shown later.

It is of interest to determine what the effect on $t_1$ would be of a somewhat different choice of $R_1$ if the values of $R_{bc}$ or $V_2$ were estimated differently.

*Figure 14* shows the effect $R_1$ has on the value of $t_1$ if all other design requirements remain the same. In a usual *RL* timing circuit, a greater resistance produces a lower value of time. However, the value $R_1$ appears in the logarithmic portion of the time equation which, in this case, has a predominance in its variation.

*Figure 15* illustrates the effect the approximation of $R_{bc}$ has on the final result. As indicated in the figure, an error of some 50 percent in the estimate of $R_{bc}$ would only contribute a 5 per cent error in $t_1$ assuming the same value of $V_2$.

The effect of $V_2$ on $t_1$ as shown in *Fig. 16* is almost linear if the value of $R_{bc}$ is assumed to be the same value. A value of $V_2$ within 10 millivolts of that estimated will give no more than 5 per cent deviation in the value of $t_1$. Also, note that for the usual case, if a slightly higher value of $R_{bc}$ had been estimated, it is very likely that a lower value of $V_2$ would have been estimated. To a certain extent these are compensating errors.

While no particular study of the effects of temperature has been made, it is known that the value of $V_2$ will decrease with increasing temperature at a rate of one to three millivolts per centigrade degree. The value of $t_1$ will then increase for increasing temperatures. For the example previously used, this would yield an approximate change of $t_1$ of some one percent per centigrade degree. Other effects may be present which would increase or decrease this figure.

### Alternate Monostable Operation

As explained earlier and as indicated in *Fig. 3*, there are two biasing conditions which will allow monostable operation. The preceding study dealt only with the condition illustrated by load line 3 of *Fig. 3*, where the steady state condition is a low voltage, high current point.

If the monostable circuit of *Fig. 7* were operated under the conditions of load line 4 of *Fig. 3*, a negative trigger voltage would be required to reduce the current through the tunnel diode to a value below the valley current. The graphical operating path is shown in *Fig. 17* and the resulting output voltage is shown in *Fig. 18*. Advantages of this circuit are a lower standby current, a higher permissible load resistance and a lower value of inductance. It does require a greater amount of trigger power and gives the waveform of *Fig. 18* which may or may not be disadvantageous.

Rearranging the components of the circuit of *Fig. 7* into the form of *Fig. 19* produces a monostable circuit

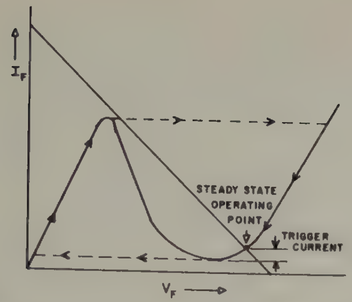


**Fig. 17—Operating path with low-current, high-voltage steady state condition.**

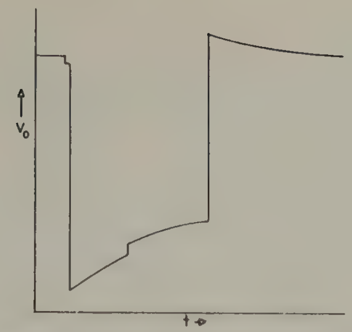


**Fig. 18—Output waveform for the condition of Fig. 17.**

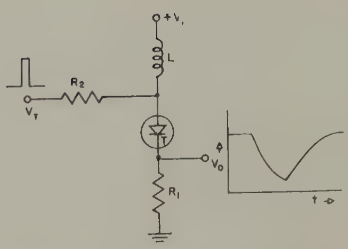


**Fig. 19—Tunnel diode monostable inverter.**

with an inverted output if the bias conditions shown in *Fig. 17* are retained.

All of the circuits shown will trigger from either a pulse or a *dc* source providing the triggering current is not enough to hold the diode in the "on" or triggered condition. As long as the trigger voltage is present, a series of repeating pulses will be produced at the output. In some cases it may even be desirable to take advantage of the locking feature using a *dc* triggering voltage.

If the supply voltage is properly adjusted, it is even possible to obtain bistable operation using the circuit of *Fig. 7*.

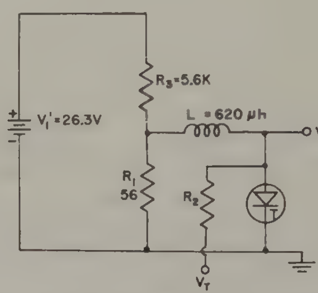


**Fig. 20—Monostable circuit tested.**

### Experimental Results

A monostable circuit was designed according to the procedure given previously in an attempt to verify the analysis. The diode used was found to possess the following characteristics:

$$
\begin{aligned}
R_{ad} &= 6 \text{ ohms}\\
R_{bc} &= 12 \text{ ohms}\\
I_P &= 4.4mA,\ V_P = 50mv\\
I_V &= 0.95mA,\ V_V = 250mv\\
C_S &= 1300pf, \text{ (at point "a")}
\end{aligned}
$$

An operating point of 4.0 milliamperes was chosen with a supply voltage of 263 millivolts and a load resistance of 56 ohms. The required value of the inductor, *L*, was calculated to be 620 microhenries for a pulse width of 10 microseconds.

The actual test circuit used is shown in *Fig. 20*. By use of the voltage divider network comprised of resistors $R_1$ and $R_3$, the low voltage supply voltage $V_1$ is obtained from the higher supply voltage. A very low output resistance power supply could have been used.

The pulse width obtained was 10.5 microseconds as indicated in the photograph of *Fig. 21*. It is of interest to note that the top of output waveform does not possess the concave shape as predicted by the analysis and shown in *Fig. 11*. This is mainly due to the curvature of the diode characteristic.

Variation of the pulse width as a function of supply voltage is shown in *Fig. 22*. Laboratory results agree

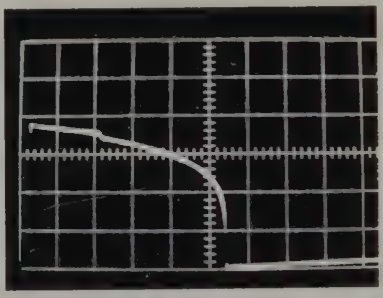

**Fig. 21—Output pulse waveform obtained. Horizontal, 2μs/cm; vertical, 100 mV/cm.**

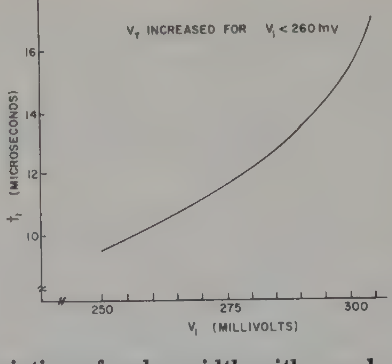


**Fig. 22—Variation of pulse width with supply voltage for the circuit tested.**

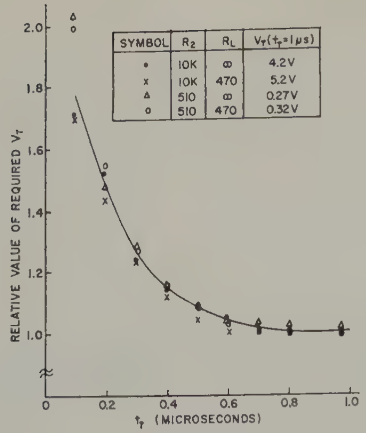


**Fig. 23—Required trigger voltage as a function of trigger pulse width.**

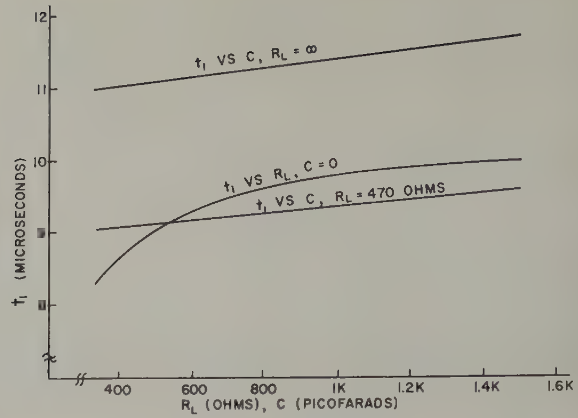


**Fig. 24—Effects of capacitive and resistive loading.**

with the calculated voltage sensitivity factor of 0.9 per cent per millivolt.

Calculation of the recovery time, $t_2$, yields a value of some 23 microseconds. Measurement showed that if an input trigger pulse appeared sooner than approximately 18 microseconds after the fall of the output, no triggering would occur. With the trigger voltage reduced to a value just sufficient to trigger the monostable, the recovery time appeared to be quite close to the value predicted.

The particular diode used possessed a very high capacitance (approximately 1300*pf* in the negative resistance region) and thus the rise time was limited to some 90 nanoseconds.

Effects of the high shunt capacitance again showed up in the trigger width requirement. A plot of the required trigger voltage as a function of pulse width is shown in *Fig. 23* for two values of $R_2$.

Results of capacitive and resistive loading tests are shown in *Fig. 24*. Close agreement between measured values of $t_1$ and those calculated was obtained for the resistive loading.

Under conditions simulating another tunnel diode for the triggering source, and with a pulse width of roughly one microsecond, the maximum repetition rate was some 300 kilocycles per second. With tunnel diodes having less capacitance (devices with the same peak current and with considerably less than a hundredth the capacity are available) the maximum repetition rate would be much higher.

Tunnel diodes with lower capacitance would also have better switching times and would require less trigger pulse width.

### Practical Uses

The tunnel diode monostable multivibrator which has been described is mainly useful where simplicity is the main feature or where very short trigger pulses of low voltage are available. Pulse width is relatively constant for a wide range of trigger width and amplitude values.

In some cases it may be desirable to use the tunnel diode monostable multivibrator between a transistor monstable and the trigger source.

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# Photovoltaic Conversion of Solar Energy

C. A. ESCOFFERY*

**The need to develop new sources of energy and the possibility of relieving the world energy problem by conversion of solar radiation is presented. The preparation and characteristics of silicon solar cells is discussed and a large assembly of solar cells capable of lighting a 100-watt lamp is described. Depending on quality and quantity, present day power cost of silicon solar cells is about $25 to $400 per watt, whereas the energy cost is less than $5 per kilowatt hour, which is smaller than what is usually paid for flashlight batteries. Future developments should drop the energy cost to less than $0.50 per kilowatt hour.**

THERE IS AN URGENT NEED to develop new sources of energy. The seriousness of our dwindling fossil fuel reserves (coal, gas, and oil), the rapid rise in world population, and the increasing per capita demands for more and still more energy are contributing factors.

Military considerations also indicate the necessity of developing new energy sources. There is, for instance, the need for light-weight, long-life, trouble-free accessory power supplies in space vehicles. There is also the problem of high cost and unavailability of fuel and of power in remote and isolated terrestrial regions. This last problem is also a civilian one.

Let us briefly consider some facts pertaining to the world energy problem.[1]

1. The present world population is about 2.4 billions and is expected to reach 6 to 8 billions in the next century.
2. In the first 18½ centuries of the Christian era the total world consumption of energy did not exceed 9Q (that is, $9 \times 10^{18}$ Btu). In the succeeding century (1850-1950), however, we used up 4Q.
3. In 1850 the annual rate of consumption was about 0.01Q; in 1950 it had multiplied ten times —to about 0.1Q.
4. The energy consumption of the world during the coming century is estimated at about 487Q.
5. The world's total economically recoverable fossil fuel reserves is estimated at only 27Q.

It is thus apparent that unless new sources of energy are soon developed the world faces an energy bankruptcy.

Fortunately, the sun provides us with a continuous source of power of incredible proportions. The sun is pouring out energy at the prodigious rate of $3.9 \times 10^{23}$ kw. If you are more familiar with other units, this corresponds to about $5.2 \times 10^{23}$ hp. $1.3 \times 10^{27}$ Btu per hr., $5.4 \times 10^{27}$ calories per minute, or 137 trillion ($10^{15}$) tons of bituminous coal per second!

Although the amount of solar radiation reaching our outer atmosphere is slightly less than one 2-billionth of the above, it still is a tidy $1.8 \times 10^{14}$ kw. or more than 0.6Q per hour.*

The amount of solar energy reaching the surface of the earth varies with atmospheric and geographic conditions. An atmospheric transmission coefficient of about 0.7 to 0.8 may be obtained on clear, cloudless days,[3,4] the upper extreme only being realized in very pure air at high altitudes. Under less optimum conditions, this figure is, of course, smaller.

In any event, from a power utilization viewpoint, most of the sunshine reaching the ground is wasted. For instance, if we could harness, at 100 percent efficiency, all the solar energy that falls on a little more than 6000 square miles of the earth's surface, we could supply all of the world's current needs.[5]

The direct collection of solar energy as heat is, at present, much more efficient than the conversion into other forms of energy, and the temperature of energy collected can be comparatively low if it is to be used for the heating of homes and buildings.[6]

It is quite possible, however, that the hope for the large-scale conversion of sunshine into useful energy lies in the photovoltaic process.

By means of a photovoltaic converter such as the silicon solar cell, solar radiation is directly transformed into electric power without an intermediate heat cycle. The absence of moving parts, the simplicity and reliability of operation, and the indefinite life expectancy, makes the process extremely attractive. Not to be discounted, also, is the absence of radioactive waste disposal problems.

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*The solar constant, or the rate at which energy is received upon a unit surface, perpendicular to the sun's direction, in freespace at the earth's mean distance from the sun has been reported by Johnson[2] as 2.00 calories per $cm^2$-minute. This corresponds to 140 mw. per $cm^2$. A figure of 100 mw. per $cm^2$ which can be obtained at the earth's surface in full sunlight is conveniently referred to as "one sun" in evaluating and testing silicon solar cells.

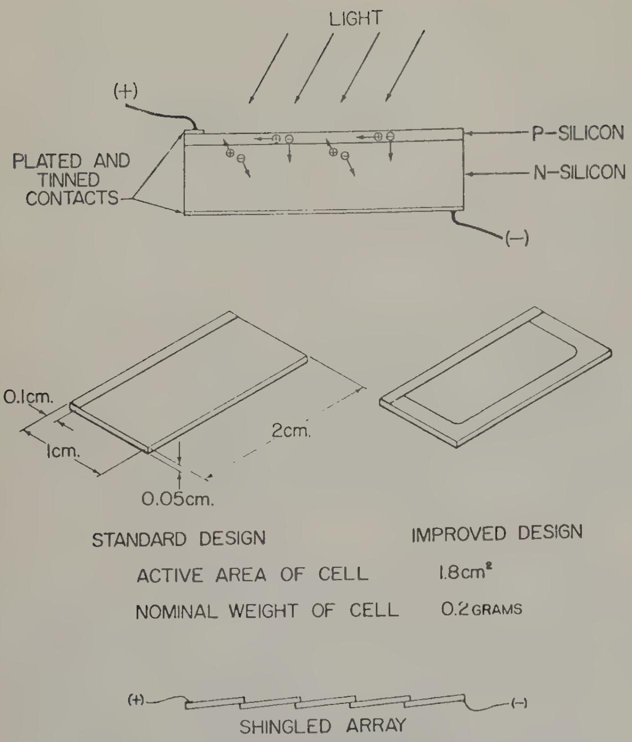


**Fig. 1—Schematic representation of silicon solar cells.**

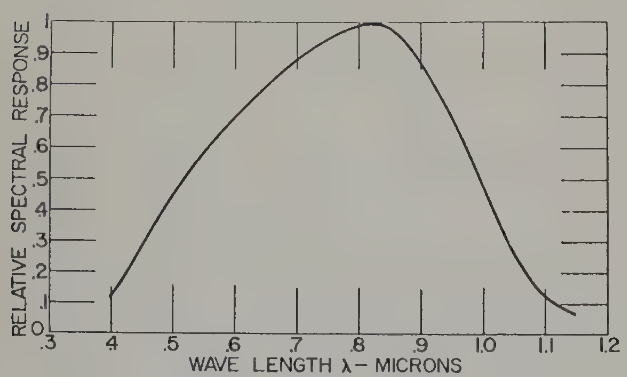


**Fig. 2—Spectral response of a silicon solar cell.**

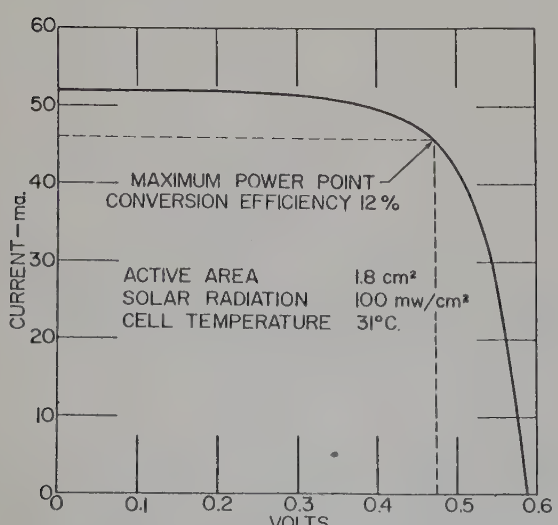


**Fig. 3—Voltage-Current characteristic of a 12% silicon solar cell.**

Although many other materials are capable of generating electric power under the influence of light, silicon is at present the most efficient and most highly developed. Consequently, this article will deal with silicon solar cells and their characteristics. No attempt will be made to present a detailed theoretical account, which can be found elsewhere.

Physically, silicon is classified as a semiconductor. Chemically, it ranks next to oxygen as the world's most abundant element.

When used for semiconductor devices like rectifiers, transistors, and solar cells, silicon must be refined and highly purified, often to impurity levels of 1 part per billion. In addition, it is necessary to prepare it in monocrystalline form in order to take full advantage of its electronic properties.

In manufacturing solar cells, which consist of *p-n* junction diodes prepared by the diffusion method, wafers of *n*-type silicon are carefully ground, lapped, and chemically etched, and then placed in a quartz tube furnace at a temperature of about 1150°C. Herein, vapors of a boron compound are passed for several minutes over the silicon, where they decompose into elemental boron which diffuses into the surface creating a thin, *p*-type silicon layer less than 0.0001 inches in thickness.

After the wafers have cooled, the *p*-layer is removed from the sides and rear surface so as to expose the original *n*-silicon. Suitable ohmic contacts are then attached to both sides of the *p-n* junction by means of appropriate plating and soldering techniques. *Fig. 1* (not drawn to scale) indicates a schematic representation of a silicon solar cell.

The spectral response of silicon solar cells lies mainly in the visible and near infrared regions of the solar spectrum, peaking at about 0.8 microns (*Fig. 2*). Incident radiation of wave length shorter than about 1.1 microns is capable of being absorbed in the top portion of the solar cell and can be directly converted into electricity.

The photons of light which are absorbed break up electron-hole pairs.[7] The electrons and the holes liberated near the *p-n* junction are influenced by the junction field so that electrons move to the *n*-side and holes to the *p*-side. A voltage difference appears across the cell terminals and if the latter are connected by means of an external circuit, an electric current will flow and can be made to do useful work.

When the silicon cell was first announced in 1954 by its inventors at the Bell Telephone Laboratories,[8] the nominal solar energy conversion efficiency (at room temperature) was given as 6 percent. This was about ten times better than the selenium cell, the best previously known photovoltaic converter.

Since then, continued research and development has raised the conversion figure of merit to 14 percent, with production quantities of cells available in the range of 10-12 percent. Because of the nature of light and of silicon, the theoretical maximum effi-

ciency is estimated to be less than 20 percent.[9]

*Fig. 3* illustrates the voltage-current characteristics of a 1 x 2 cm silicon solar cell of 12 percent conversion efficiency. This cell was constructed by the improved design shown in *Fig. 1*, wherein a very narrow collector grip loop is applied to the top exposed surface. The reduction in active area by the loop is negligible whereas the decrease in the series resistance of the cells is pronounced. This is indicated by the more rectangular shape of the *V-I* curve than obtained on lower efficiency cells and by the higher voltage at the optimum power transfer point (matched loading).

*Fig. 4* illustrates how the output characteristics of a solar cell vary with the amount of incident radiant power. For any given spectral distribution, variation of the short circuit current is linear with radiation intensity. The same is true for the output current at maximum power transfer. Above about 40 mw/cm$^2$, the variation in output voltage at maximum power is small and almost linear. Below this point, the voltage decreases more rapidly.

Solar radiation outside our atmosphere is more intense and of a broader spectral range than at the earth's surface. Since the intensity increase, however, occurs to some extent in spectral regions where the cell is not very sensitive, there is not a proportional increase in cell output. Other things being equal, a solar cell calibrated on earth at 100 mw/cm$^2$ solar radiation intensity to deliver 10 mw/cm$^2$ with a conversion efficiency of 10 percent, will deliver approximately 12 mw/cm$^2$ at zero air mass with a conversion efficiency of about 8½ percent.

*Fig. 5* illustrates the influence of cell temperature on the maximum power output, the voltage at which the maximum power is obtained, and the open circuit voltage. Above room temperature, the maximum power output decreases linearly at a rate of approximately 0.5 percent per degree C. The temperature rise of a solar cell exposed to sunlight will depend on the rate at which it loses heat to its surroundings; hence, any design for a solar cell energy converter should provide for adequate heat dissipation.

For application in satellites and other space vehicles, it is customary to cover the active cell surface with a very thin (0.003-0.005 inches) glass cover slip which yields a high value of thermal emittance at infrared wave lengths. The glass surfaces are provided with an ultraviolet reflecting film to avoid degradation of the organic cement bonding the glass to the cell, and with another vacuum deposited film designed to reduce reflection losses from the glass.

By the above means it is possible to maintain low cell temperatures and prevent unnecessary reduction in output power due to temperature rise. Research is presently being conducted on specially deposited thin films of silicon oxides designed to replace the cemented glass covers. These films are able to raise the average thermal emissivity of the silicon (40°C) from a value of about 0.3 to over 0.7, and with negligible if any loss in transmission.

The weight of a 1 x 2 cm solar cell is only about 0.2 grams. Since the output of a 12 percent cell (1.8 cm$^2$ active area) in full sunlight (100 mw/cm$^2$) is about 21.6 mw, this corresponds to a figure of merit of 108 mw/g, or 49 w/lb.

The life expectancy of the cell is believed to be indefinitely long, hence it is difficult to arrive at an energy per weight figure of merit. If a conservative value of 10,000 operating hours is used, we obtain a figure of 490 kw-hr/lb for unsupported cells.

The weight of the supporting structure is, of

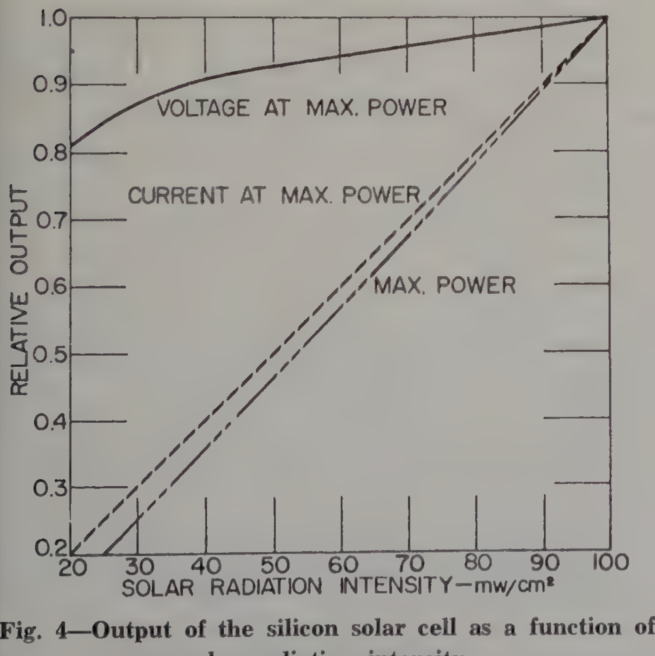


**Fig. 4—Output of the silicon solar cell as a function of solar radiation intensity.**

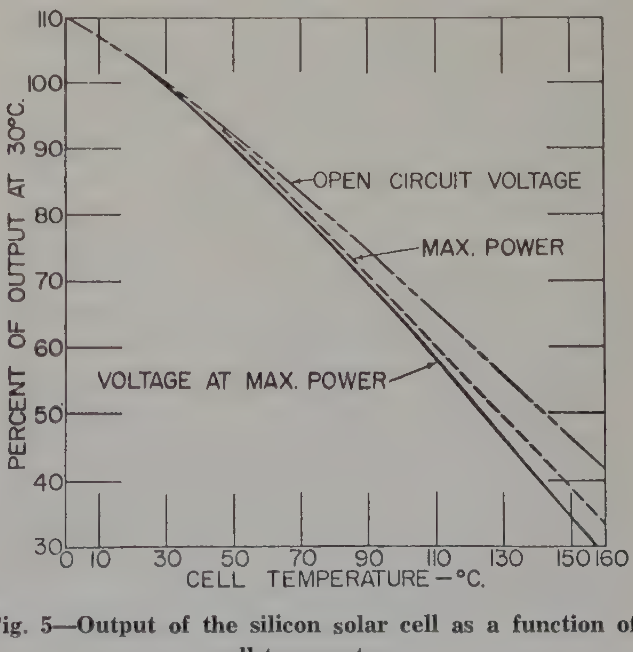


**Fig. 5—Output of the silicon solar cell as a function of cell temperature.**

course, a matter of design. Honeycomb structures of aluminum and polyester impregnated fibre glass have high strength-to-weight ratios, with weight-to-area ratios of less than one lb/ft$^2$.

Studies are being made which utilize ultra light weight techniques such as thin metal foil, metal-clad plastic films, woven glass, and screens of metal or glass. These can be stretched over "picture frames" and hinged to form compact folded arrays which can be extended to full area as desired, or they can be left unmounted to take advantage of their flexibility.

Solar cells are connected in series for increased voltage output and in parallel for increased current. The power output depends not only on the number of cells but also on the space utilization. "Shingling," or overlapping of cells (*Fig. 1*), provides the highest output per unit area. In this assembly, the entire exposed surface with the exception of the collector strip on the end cell, is an active area. In many cases, it is preferable to mount the cells side by side in the same plane. In a series-connected string, the cell with the lowest current output will determine the overall current, hence care must be taken to insure adequate current matching. For a parallel connection, voltage matching is more important.

*Fig. 6* illustrates a large single panel ("The Solar King") utilizing solar cells. The unit, which measures 26 ft$^2$, employs 10,640 cells of 4-5 percent efficiency. With an open circuit voltage in full sunlight of over 115 volts and a short circuit current of about 1½ amperes, it is capable of lighting a 100-watt incandescent bulb. The panel mounts on the top of an electric automobile, where it is used to charge the 72-volt storage battery.

As with many other goods, cost of silicon solar cells varies with the quality and quantity. The high efficiency cells cost about \$200-\$400 per watt. Medium efficiency cells (5%) in large quantities cost much less, approximately \$25-\$100 per watt. Discounting the cost of auxiliary storage devices, this initial investment cost spread over a life span of at least 10,000 sunlight hours yields an energy cost figure of about \$2.50/kw-hr., which is less than we now pay for primary electrochemical cells, such as flashlight batteries.

Improved processing techniques are currently being investigated for producing large area, medium efficiency silicon solar energy converters. When these techniques are translated into production and widespread use is made of them for the large scale conversion of solar energy, it is expected that the cost may tumble to less than \$0.15 per square inch, or about \$5.00 per watt. Again, this spread over a conservative life span of 10,000 sunlight hours, corresponds to \$0.50 per kw-hr. Obviously, the main economic problem is now one of reducing the cost of storage-battery systems.[10]

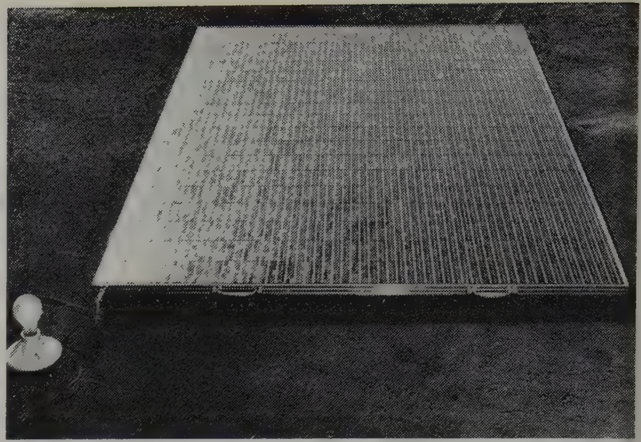

**Fig. 6—A 26 sq. ft. panel with 10,640 silicon cells (1 x 2 cm. each) lighting a 100 watt bulb.**

The present intensive study on fuel cells leads to the hope that a suitable system will be developed wherein water is electrolyzed to yield hydrogen and oxygen which are fed into a hydrox cell for power generation. The water would be electrolyzed by electricity generated through the photovoltaic conversion of solar energy. In any event, with an efficient energy storage system, a 5% solar cell converter in a suitable location could yield a continuous (24 hr.) daily output of about 1 w/ft.[2]

The technical and economic aspects of the utilization of solar energy by photovoltaic conversion indicate that before long it will be widely used to complement other power sources.

Eventually, as someone has phrased it, we may be spinning the wheels of our industrial civilization by means of sunbeams.

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# A Survey of Semiconductor Devices and Circuits In Computers

## Part 1

VELIO A. MARSOCCI*

**A study of the status of semiconductor applications in electronic computers is presented. A review of the basic theory pertaining to the switching aspects of conventional transistors is briefly reviewed, and a survey is made of conventional transistor devices and the problems encountered in their fabrication. The point of view taken is toward the improvement of the switching characteristics of transistors. The general performance of switching circuits is considered and the methods by which increases in their switching speeds may be obtained are described. Several non-regenerative types of switching circuits are first discussed with some observations made with regard to the logical aspects of these circuits. Regenerative switching circuits making use of semiconductor devices are then taken into account and their role in computer operations is outlined. The discussion then progresses to some of the newer devices such as tunnel diodes and parametric phase-locked oscillators which make use of semiconductor elements. Although the applications of semiconductors in digital computers is stressed, some attention is given to the problems encountered in analog computers.**

### Introduction

The advent of various semiconductor devices in the past decade has given considerable impetus to the development of electronic computers. The semiconductor devices have provided a means of appreciably reducing the size, weight and input power requirements of computer systems, and have increased the reliability of these systems when proper design techniques have been employed. This article presents a survey of the semiconductor devices and circuits which find application in present-day electronic computer systems. Obviously, not all the possible aspects of the subject can be included here, but those devices which are already, or most likely to be, employed in computer systems will be considered. Similarly, the great number of different semiconductor circuit configurations and modifications which may be designed makes it impractical to attempt a complete coverage of all possible circuitry. Nor does this article represent an attempt to discuss the general theory of semiconductor circuit design. The attitude taken is to discuss typical devices and circuits from the point of view of the problems peculiar to electronic computers.

Recently, several completely transistorized digital computers have been announced. The RCA 501 and IBM 608 systems have been developed as business computers, and the Burroughs Corporation B251 computer has been designed specifically to handle banking problems. Control Data Corporation has developed the 1604 computer, which requires only two power supply and two signal levels. A completely transistorized computer with an automatic program control, the DE-60, has been announced by Clary Corporation. Other transistorized digital computers include Philco Corporation's airborne computer TRANSAC-1 which utilizes some 1400 surface barrier transistors in its arithmetic section, Remington Rand's LARC with some 5000 to 8000 transistors and over 25,000 diodes, IBM's STRETCH and transistorized version of the 604 and North American Aviation's RECOMP. The TX-2 at the MIT Lincoln Laboratories and the first transistorized military digital computer, TRADIC, might also be mentioned. The Bureau of Standards' SEAC computer, although not transistorized, makes use of germanium diodes in its circuitry.

Among the foreign digital computer systems are the Mosaic and the Metrovick which are produced in Great Britain. The Mosaic computer makes use of some 2000 germanium diodes and the Metrovick computer's arithmetic section is transistorized. The Gamma 3, produced in France, makes use of some 7000 germanium diodes. Another foreign computer employing semiconductor devices is the X-1 in Amsterdam. Transistorized analog computers presently in use include the Electronic Associate's TR-10, the TRIDAC, and a general purpose airborne computer developed by North American Aviation. A transistorized analog computer was also shown by Russia at the 1959 Russian Exhibition in New York.

Since semiconductor devices have, up to the present time, found greater application in digital computers than in analog computers, the emphasis in the following discussion will be placed on the switching characteristics of semiconductor devices and on logic circuits. A brief review of conventional transistor theory is given to point out the necessary requirements on transistor geometry for good switching properties and

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high power-handling capabilities, and the fabrication of several conventional transistor types is then described from the viewpoint of these requirements.

A discussion of semiconductor diodes, four-layer transistor structures, tunnel diodes, parametric phase-locked oscillators and typical computer circuits employing these devices is included. The application of transistors in analog computer systems and the special problems encountered in transistorized analog computer circuits is considered briefly.

### Basic Theory and Devices

Prior to an inspection of the various transistor types in use, it may be advantageous to review briefly the principles of the device characteristics which determine whether a particular transistor will be successful when used for computer applications. The primary requirements for the active devices used in digital computer operations are high switching speeds, adequate gain and the capability of handling the power levels specified for the system. Each of these requirements will be considered in turn.

It is well known from the general theory that for an active device to respond to a high-speed transient, and to reproduce that transient as an output with little degradation in the transient characteristic, the device must possess a good high-frequency response, providing sufficient gain (the sufficiency is determined by the application) over a wide band of frequencies. It is of importance to the transistor designer that some clear relationship be established between these desired characteristics and the physical properties and the geometry of the transistor material. This relationship will now be examined.

Although the equations which follow apply to the low-frequency characteristics of transistors, they will be used here, for the sake of simplicity, to provide a basis for showing the interrelation of frequency response, gain, power-handling capability and the physical characteristics of the transistor.

From transistor physics, it has been derived[21] that $\alpha_{fb}$, the common-base short-circuit current gain, is given approximately as

$$\alpha_{fb} \doteq 1 - \frac{1}{2}\left(\frac{W}{L_b}\right)^2 - \frac{\rho_e}{\rho_b}\frac{W}{L_e} \qquad (1)$$

where $W$ = base-layer thickness.
$\rho_e$ = resistivity of the emitter material.
$\rho_b$ = resistivity of base material.
$L_e$ = diffusion length of minority carriers in the emitter region.
$L_b$ = diffusion length of minority carriers in the base region.

Whereas the common-emitter short-circuit current gain, $\beta$, is related to $\alpha_{fb}$ by

$$\beta = \frac{\alpha_{fb}}{1 - \alpha_{fb}} \qquad (2)$$

then, by making the assumption that $\alpha_{fb} = 1$ in the numerator of Equation (2), and by substituting (1) into (2), the following result is obtained:

$$\beta \doteq \frac{1}{\frac{1}{2}\left(\frac{W}{L_b}\right)^2 + \frac{\rho_e}{\rho_b}\left(\frac{W}{L_e}\right)} \qquad (3)$$

The above equations also assume a one-dimensional model of the transistor action, that is, the current densities and the electric fields existing in the transistor are assumed to have a homogeneous distribution in any plane perpendicular to the principal axis of the transistor.

The cutoff frequency, $f_{ab}$, is defined as the frequency at which the common-base short-circuit current gain, $\alpha_{fb}$, falls to a value 3 *db* down from its nominal low-frequency value, where it is assumed that the high-frequency response of $\alpha_{fb}$ is asymptotic to *a* —6 *db* per octave slope. This cutoff frequency may be expressed as a function of the base-layer thickness of the transistor by[8]

$$f_{ab} = \frac{1.21\ D_b}{\pi\ W^2} \qquad (4)$$

where $D_b$ is the diffusion constant for the minority carriers in the base region. It will be assumed here that the cutoff frequency represents the useful bandwidth of the device. The common-emitter cutoff frequency, $f_{ae}$, may be computed from $f_{ab}$ by

$$f_{ae} = f_{ab}\ (1 - \alpha_{fb}) \qquad (5)$$

It has been pointed out by Clark that $f_{ab}$ is not strongly dependent on the thickness of the base region. This may be seen by substituting Equations (1) and (4) into (5). Therefore, Equation (4) which expresses the dependency of $f_{ab}$ on $W$, is of greater interest in relating the frequency response to the geometry of the transistor.

From the equations presented it is apparent that a good high-frequency response may be attained by a thin base-layer construction, as this will tend to augment both $\beta$ and $f_{ab}$. However, a decrease in the base width, $W$, will result in an increase[16] in the base spreading resistance of the transistor which will tend to reduce power gain at the higher frequencies. An attempt to reduce the base resistance by decreasing the resistivity of the base material will, in turn, result in a decrease in the emitter efficiency and an increase in the collector capacity. These two effects will be manifested by a decrease in current gain and in high frequency response. However, to keep the current gain and frequency response of the transistor intact the choice of a thin base layer is imposed on transistor designers. A somewhat more intuitive approach may be taken by considering that a short transit time for the minority carriers in the base region is a constraint on good high-frequency response. This approach also leads to the obvious choice of a thin base region.

Further, the available power gain of a transistor

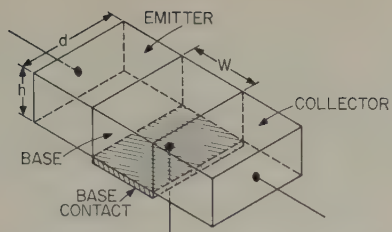


**Fig. 1—Model of a junction transistor.**

with a base depth $d$ and a height $h$, as shown in *Fig. 1*, is given by[15]

$$G \doteq K\left(\frac{d}{h}\right)^{\frac{1}{2}}\frac{1}{A} \qquad (6)$$

where $K$ is a constant and $A$ is the cross-sectional area, $d \times h$. It may be observed from Equation (6), that for a fixed cross-sectional area, a long thin base-layer[1] configuration should be employed with the base contact on the long dimension. However, it may also be noted that the most predominant factor in providing high gain is a reduced value of the area, $A$. It has also been derived[1] that, for a fixed area, $A$, the base resistance is reduced if a long line type of base contact is used. If the effects of high current densities are investigated, the conclusions reached also indicate the desirability of a long emitter edge (dimension $d$ in *Fig. 1*).

However, certain practical disadvantages accrue from the specification of a narrow base region. The predominant and most obvious one is the difficulty of fabrication. The techniques used in the attempt to surmount this problem will be discussed later. Additionally, the width of the collector space charge region is modulated by the applied junction voltage, and increases as the reverse collector voltage is increased. A point is reached where the effective base region disappears with the collector space-charge region coming into direct contact with the emitter, thus breaking down the transistor action. This phenomena is the so-called "punch-through effect." The required voltage conditions under which a transistor must operate therefore set a limit on the minimum width of the base region.

The power-handling capability of a transistor is directly related to its ability to dissipate internally developed heat. The power requirements desired for a particular transistor therefore set a limit on the minimum physical dimensions of the transistor materials. Large sized junction areas are required for good heat transfer as well as for proper operation at high current densities.

It would appear, then, that the transistor designer is faced with a conflicting set of design criteria; the requirement of a thin base region and small junction areas for good high-frequency response on the one hand, and the requirement of a wide base region and large junction areas for adequate voltage and power-handling capabilities on the other. Obviously, a design compromise must be made to favor that characteristic which is of greatest importance in any particular application.

There also exist the additional requirements of a low collector cutoff current, $I_{co}$, and a low collector saturation voltage, if the transistor is to simulate good switching action when used as a full-driven or over-driven switch. Ideally, a perfect switch will pass no current when in the *off* (or open) condition, and will produce no voltage drop across itself, when in the *on* (or closed) position. In addition, the switching characteristic is affected by delays introduced by minority carrier storage in the base region. This phenomenon will be discussed later.

The techniques used to improve the high frequency characteristics of transistors while satisfying power and voltage requirements will now be considered by surveying the present methods of transistor fabrication.[27] At first, only the conventional triode type of transistor shall be discussed so that the basic ideas may be made clear. Later, the more exotic types of transistors will be studied.

### Point-contact transistors

The point contact or type "A" transistor[25, 31] is constructed by placing two fine phosphor-bronze wires a few thousandths of an inch apart on a piece of $n$-type semiconductor material and "forming" contacts by the application of heat and pressure. The leads then become the emitter and the collector, with the base layer made up of the semiconductor material. The fine wires which form the transistor leads necessarily limit the current-handling capacity of this type of transistor, although the device can be made to exhibit a high cutoff frequency by proper spacing of the contacts. The action of the point contact transistor and the method of controlling the dimensions of the base region are poorly understood, and the devices have been almost entirely by-passed by transistor research.

### Grown Junction Transistors

This transistor type is produced[2, 25, 31] by dipping a crystal seed into a melt of silicon or germanium material, and then slowly raising the seed out of the liquid. In this way, a single crystal will be drawn from the liquid. By the proper addition of impurities during the growing process, alternate regions of $n$ and $p$ type material are formed. Transistor bars, either $n$-$p$-$n$ or $p$-$n$-$p$, are cut from the single crystal, and a method of either alloying, soldering, or diffusing is used to produce a contact with external wire leads.

Variations on this process may be employed to provide narrow base regions. In the grown-diffused[13] process the crystal growth is stopped after the collector region is formed. The impurities for the base and emitter regions are then added, and as the crystal growth is resumed the impurities diffuse into the collector to form a thin base region. The diffused-melt-

back[13, 23] process involves doping a single semiconductor crystal, during growth, with both acceptor and donor type impurities. The crystal bars are then remelted and, upon solidification, the resulting distribution, due to diffusion in the bar, is such that $n$ and $p$ regions are formed. By proper control of the impurity concentrations the formation of narrow base regions is possible.

Grown junction transistors with alpha cutoff frequencies near 10 *mc.* have been produced. The power rating of these transistors is usually below one watt. The grown-diffused and the meltback techniques have extended the range of operating frequencies to about 100 *mc.*

### Alloy Junction Transistors[4,25,3]

The emitter and the collector regions in the alloy junction or fused junction transistor are formed by placing indium pellets (for a *p-n-p* transistor) on opposite sides of a slab of *n*-type germanium. The structure is then heated until the pellets are fused to the semiconductor material. The areas near the pellets are formed into *p*-type regions by the fusing process, resulting in a *p-n-p* structure with the germanium slab consituting the base. As the greatest part of the *p-n-p* structure forms the base region, the frequency response of alloy junction transistors is limited. However, the sturdy construction of this transistor type permits power dissipation ratings up to 100 watts.

### Surface Barrier Transistors

The surface barrier transistor [4,25,31] is another outgrowth of the attempt to produce transistors with very thin base regions. The base region is produced by allowing two jets of an electrolytic solution to etch opposite surfaces of a semiconductor disk. The jet solution contains the material with which the disk is to be plated. An electrical bias, with reversible polarity is provided between the jets and the semiconductor disk. At first, the polarity is arranged so that pits are etched into both faces of the disk until a penetration of within a few ten-thousandths of an inch of each other is achieved. The polarity is then reversed, allowing the electrolytic jets to plate the etched surfaces forming emitter and collector regions. Transistors of this type have their greatest application in high-speed circuitry because of their improved high-frequency characteristics; but their power-handling capacity is limited by the small electrode areas which result. Surface barrier transistors operate at frequencies in the region of 50 *mc.* to 100 *mc.*, but with power ratings of the order of 100 milliwatts or less.

The micro-alloy diffused base (MADT) [2,4,25,29,31] transistor, a modification of the surface barrier transistor, is formed by etching emitter and collector pits into opposite faces of a base layer material and then plating electrodes in the pits. The penetration of the plating in this case is held to an extremely shallow dimension, less than 0.01 mils. The MADT technique has produced very high-speed switching transistors with turn-on and turn-off times of less than ten millimicroseconds. These transistors are capable of operating at frequencies up to approximately 5000 *mc.*, at a power dissipation rating of about 100 milliwatts.

### Diffused Junction Transistors

The diffused junction [2,4,25,31] process of transistor fabrication consists of either of two methods. A slab of semiconductor may be plated with an impurity material, and then heat treatment will cause the impurity to diffuse short distances into the semiconductor forming the base layer. An alternate method in use is to produce the diffusion by heating the semiconductor slabs in a furnace filled with impurities in a vaporous state. Base thicknesses of 0.00002 inches are achievable. After the diffusion process, the emitter junction is formed by alloying a contact to the diffused surface. The ruggedness and the power-handling capacity of this transistor type may be increased by forming the diffused base on a small raised portion of the semiconductor material. Transistors produced in this fashion, referred to as "Mesa transistors" because of their raised plateau-like construction, combine high-speed operation with a power-handling capability better than that of other high-frequency types. As an example, the 2N1131 and 2N1132 types produced by Fairchild Semiconductor Corporation have two watt power rating with rise times and storage times of 80 millimicroseconds and 30 millimicroseconds respectively.

This completes the survey of most of the conventional triode types of transistors presently in use. Prior to a discussion of the circuits used in computer applications, it might be expedient if the subject of the semiconductor diode is first examined. Then the discussion on computer circuits can include the more general cases where both diodes and transistors are employed in one circuit.

### Semiconductor Diodes

The same general remarks concerning high switching speeds may be made for the semiconductor diode as were made for the transistor. There is associated with a *p-n* junction the phenomena of effective diffusion or storage capacity as well as effective space charge capacity. The diffusion capacity manifests itself in the following way. When the *p-n* junction, or essentially a junction diode, is conducting in the forward direction, stored minority carriers are carried across the junction, and upon the application of a "turn-off" signal to the diode, these excess stored carriers must be swept out before conduction in the diode falls to the low reverse current value. This operation results in a time delay in the switching or transient characteristic of the diode which is detrimental to the use of a diode in high-speed circuitry. The point-contact type of diode is more suitable for very high-speed pulse application than is the grown

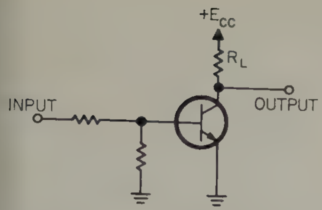


**Fig. 2—Basic transistor switch.**

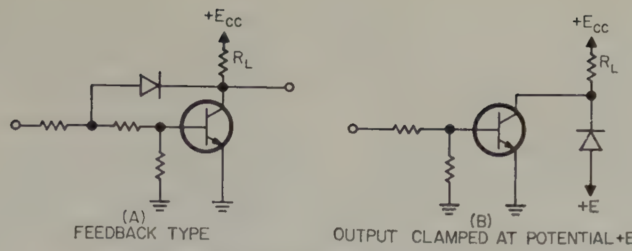


**Fig. 3—Clamping circuits.**

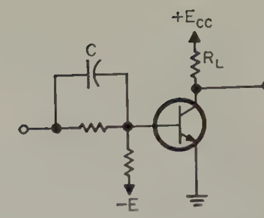


**Fig. 4—Modified transistor switch.**

junction diode since the capacitive effects associated with the point-contact diode are less than those of the grown junction diodes. The recovery times for the point-contact diodes may be in the order of a few millimicroseconds. However, the point-contact diodes suffer the disadvantage of a low current-handling ability.

### Storage Time

The presence of the diffusion and the space charge capacities affects the switching characteristics of transistors as well as those of diodes, and it might be profitable to the present discussion to review briefly the ideas involved. *Fig. 2* shows a basic transistor switch[11] which is cut off when no input signal is applied, but may be switched into conduction by the application of a positive input signal (pulse). The speed with which the transitor switches from the *off* condition to a given *on* voltage level may be increased by driving the transistor toward a higher input voltage level. As the input is increased a point will be reached when the transistor is being switched into saturation in order to provide smaller turn-on times. However, a transistor driven into saturation will not cease conduction at the instant the input level is removed due to the excess minority carriers stored in the base region. These excess minority carriers must be swept out before the output of the transistor will begin to fall-off in response to the removal of the input signal. This action results in a delay time in the transistor pulse characteristics, and represents a limitation on the minimum pulse width which a particular transistor may be capable of reproducing. The transistor pulse characteristics may be improved if measures are provided in the external circuitry to prevent saturation of the transistor. *Fig. 3* shows two methods of clamping the collector voltage of a transistor at some specified level. *Fig. 4* indicates a transistor switch[11] with an input capacitor *C* added to the input circuitry to improve the switching time. The capacitor and resistor combination act as a high pass filter to provide overdrive during the switching operation. The capacitor allows a large initial rise in the drive current when an input pulse is applied, and its polarity, when charged, will be such that it will help sweep out the stored carriers in the base region of the transistor during the cutoff time, thereby improving the switching characteristic of the circuit. The bias voltage –E is added to improve the *off* condition of the transistor switch by helping to reduce the cutoff current of the transistor.

In the discussion which follows later on resistance-coupled gating circuits, the overdrive capacitor will not be shown in the circuit diagrams. However, it should be understood that the switching speeds of the gates shown in *Figs. 9* and *10*, for instance, may be improved by the addition of overdrive capacitors in the input circuitry. Resistance-capacitance coupled logic circuits of this type, employing MADT transistors, have achieved switching rates in excess of ten megacycles. However, circuits of the resistance-capacitance coupled type suffer the disadvantages[10] that care must be taken to avoid saturating the transistors too deeply and that the capacitors provide a path into the base of the transistor for noise due to high transient currents drawn by these circuits.

*(To be continued)*

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# Applications Engineering Digests

## APPLICATIONS ENGINEERING DIGEST NO. 55

*(Circle 199 on Reader Service Card)*

***Millimicrosecond Avalanche Switching Circuits Utilizing Double Diffused Silicon Mesa Transistors;*** Fairchild Semiconductor Corp., Mountain View, Cal. (Isy Haas)

Avalanche multiplication enables one to generate short current or voltage pulses with very low rise-times. This can be achieved with ease and reliability in silicon mesa transistors.

The avalanche mode can also be used in bistable circuits, using turn-off techniques common to devices having similar characteristics. One suggested circuit is shown in *Fig. 55.1*. The load line due to $R_L$ is now chosen so that:

$$R_L < \frac{V_{cc} - LV_{CER}}{I_H}$$

where $LV_{CER}$ should be replaced by its current dependent form to determine the exact operating point. To a first approximation, the *d-c* operating point in the avalanche mode will be determined through solving the following simultaneous equations:

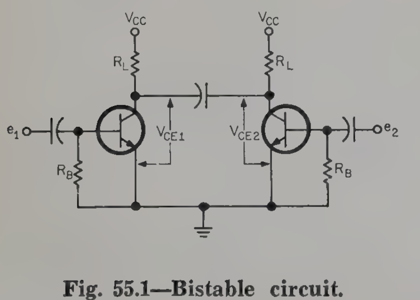


**Fig. 55.1—Bistable circuit.**

$$I_c = \frac{1}{R_L}(V_{cc} - V_{CE})$$

$$V_{CE} = LV_{CER} + (I_c - 0.1)R_A$$

when

$I_c$ = Collector current

$V_{CE}$ = Collector to emitter voltage

$R_A$ = Dynamic impedance in region II (20-40Ω in the case of Fairchild 2N696 and 2N697 transistors)

$LV_{CER}$ = Avalanche voltage at $I_c$ = 100ma

Also,

$$R_L < \frac{V_{cc} - BV_{CBO}}{I_A}$$

When a pulse is applied to one of the bases, the other collector voltage will be pulled down and turn off the device as the first one turns on. The wave forms are shown in *Fig. 55.2*. However, the major draw-back of such a circuit is that the passive-circuitry's time constants create a serious speed limiting factor and obliterate the fast switching speeds inherent in avalanche switching.

The instantaneous dissipation in the transistor may be as large as 60 watts (1 ampere at 60 volts). However, as long as the *rms* dissipation does not exceed the rating of the transistor, diffused silicon mesa transistors can handle this dissipation, the reason for this being that the current distribution through the device is forced to spread out somewhat because of the rise of the bulk resistivity with temperature.

Turn-on delay measurements have been made but are only in the order of 1 mμsec and jitter is even smaller. Since the output pulse-width can be accurately controlled, avalanche switching circuits can be used for logic, the information possibly being sampled in the same manner as in magnetic core logic. Avalanche transistors can also be used for relaxation oscillators, class C sinusoidal oscillators, trigger circuits, memory applications, etc. They are also easily adaptable to use with transmission lines because of the low impedance levels involved. ■

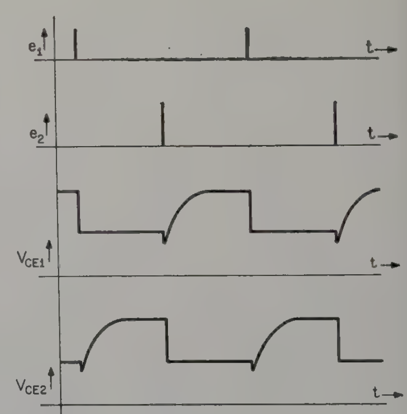


**Fig. 55.2—Waveforms in circuit of Fig. 55.1**

*(Circle 200 on Reader Service Card)*

***Use of Differential Amplifiers in Control Circuits for Silicon Controlled Rectifier;*** General Electric Co., Syracuse, N.Y.

Most of the control circuits for Silicon Controlled Rectifiers *(SCR)* which have been described to date in the published literature and application notes have used the simplest forms of the direct-coupled transistor amplifier in conjunction with *UJT* (unijunction transistor) firing circuits. These simpler circuits often meet the operating requirements of many practical applications and offer the advantage of maximum economy. However, in many cases the differential amplifier could be used to advantage. Some of the practical benefits which might be expected from the use of the differential amplifier would include:

(1) In circuits where the amplifier must work from a source having a low output impedance (1K or less) the differential amplifier offers considerably more stability with respect to changes in temperature than the simple direct-coupled amplifier. This occurs since the base to emitter voltage change with temperature is compensated for in the differential amplifier configuration.

(2) The control threshold of the differential amplifier may be adjusted as desired and will remain independent of ambient temperature. This means, for example, that the input voltage to a differential amplifier using silicon transistors may initiate control action at 0.10 volts or less rather than at 0.70 volts as required for the conventional direct-coupled circuit.

(3) A simple reversing type control can be made using the differential amplifier which may be operated from an electrical signal at a single input and which has a precisely determined deadband.

(4) Simple and sensitive reversing type phase detector controls may be made using the differential amplifier.

(5) Either linear type controls may be made or full on—full off type controls may be made using the differential amplifier.

It is the intent of this digest to give the basic design principles of the differential amplifier type control circuit and illustrate the possible circuits by means of a few simple examples.

**Basic Phase Control Circuit with the Differential Amplifier**

A simple phase control circuit using *npn* transistors in a differential amplifier circuit is shown in *Fig. 56.1.* This circuit uses a 100 ohm pot for adjusting the voltage level of the control circuit. With the circuit as shown, an increase in the input voltage level will cause a decrease in the firing angle of the *UJT* and the *SCR*'s. Note that the opposite effect can be obtained by interchanging the connections to the collectors of the two transistors.

*Figure 56.2* illustrates the use of *pnp* transistors in control circuits. The control voltage for this circuit is zero since the base of *Q2* is connected to ground. This circuit is superior to the *npn* circuit of *Fig. 3* since the control is more linear. This occurs because the capacitor in *Fig. 4* is charged from a current source (i.e. the output impedance of the transistor *Q2* is very high). For this circuit the period is given by:

$$\tau = \frac{\eta V_1 C_T}{I_{E2}} \cong \eta V_1 C_T \left[\frac{V_{in}}{R_{in}} + \frac{V_2}{2R_1}\right]^{-1}$$

and the minimum period is given by:

$$\tau_{(min)} = \frac{\eta V_1 R_1 C_T}{V_2}$$

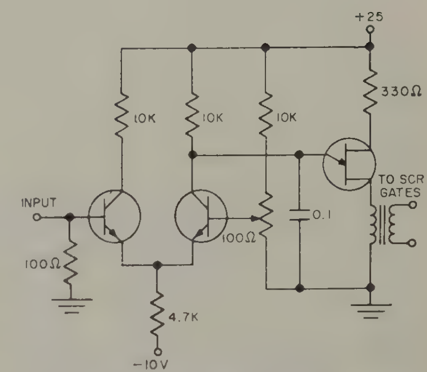


**Fig. 56.1—Basic differential amplifier circuit using *n-p-n* transistors.**

**Reversing Type Control Circuit**

A basic circuit for a reversing type control is shown in *Fig. 56.3.* This circuit shows the voltage reference as ground, but a variable reference voltage may also be used. This circuit can also use the *pnp* differential amplifier if desired.

The circuit is designed in such a way that for any value of input voltage only one of the *UJT*'s can fire during a half cycle. If the *SCR*'s are used in a full-wave bridge, the *UJT* which fires will determine the phase angle and the direction of current flow through the load. If the input voltage is reversed in polarity, the opposite *UJT* will fire and the current will flow through the load in the opposite direction.

For suitably small values of input voltage, the output from the circuit will be zero since the firing of both *UJT*'s will be delayed for more than a half cycle. The width of this "dead band" can be chosen as desired by means of the component values in *Fig. 56.3.* For example, the dead band can be varied by means of $R_1$. Increasing $R_1$ will increase the width of the dead band. ■

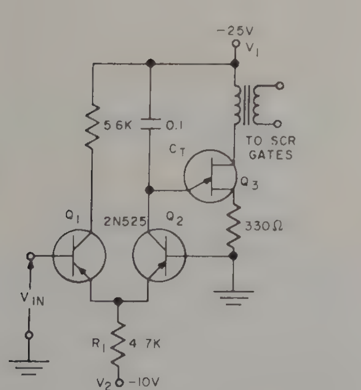


**Fig. 56.2—Basic differential amplifier circuit using *p-n-p* transistors.**

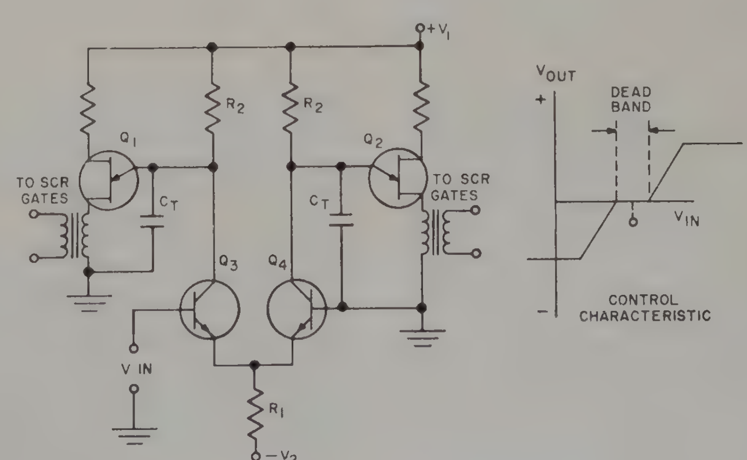


**Fig. 56.3—Basic control circuit for revising type applications.**

# PATENT REVIEW*

## Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

*Compiled by* SIDNEY MARSHALL

**The abstracts appearing in this issue cover the inventions relevant to semiconductors from Aug. 12, 1958 to September 16, 1958. In subsequent issues, patents issued from Sept. 16, 1958 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.**

**August 12, 1958**

2,847,569 Relaxation Oscillator Circuit—M. B. Finkelstein. Assignee: R.C.A. A simple transistor pulse generator providing low frequency square waves at low impedance levels, which utilizes a minimum number of components.

2,847,583 Semiconductor Devices and Stabilization Thereof—H. C. Lin. Assignee: R.C.A. A transistor-diode configuration, one arrangement of which provides a semiconductor diode having a common portion with and between the emitter and base of a transistor and arranged so as to control, in accordance with its own temperature variations, the bias voltage between the base and emitter of the transistor.

2,847,585 Radiation Responsive Voltage Sources—S. N. Christian. Assignee: R.C.A. A device for generating electrical energy in response to high energy nuclear radiation.

2,847,623 Full Wave Rectifier Structure and Method of Preparing Same—J. W. Sharnhill Assignee: Texas Instruments, Inc. A full wave semiconductor rectifier constructed to minimize the effect of mechanical shock upon its operation, and to eliminate the danger of cracked or parting leads.

2,847,624 Semiconductor Devices and Methods—I. Boldman. Assignee: Sylvania Electric Products. A process for contstructing small crystal diodes which have rapid recovery times by plating a germanium layer onto an electrode upon which a doping agent was deposited, and heat treating the structure to effect diffusion of the doping agent into the germanium layer.

2,847,625 Electrical control Apparatus—W. J. Popowsky. Assignee: Minneapolis-Honeywell Regulator Company. A transistor oscillator having variable impedance characteristics which provide a direct source of feedback energy usable in electrical or in electromechanical feedback apparatus.

2,847,645 Null-Type Transistor Alpha Measuring Set—D. E. Thomas. Assignee: Bell Tel. Labs. A circuit which permits precise measurement of transistor current amplification factors at low emitter current levels.

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

**August 19, 1958**

2,848,564 Temperature Stabilized Transistor Amplifier — E. Keonjian. Assignee: G. E. Company. A network for connecting solid state amplifiers in cascode in such a manner that the input-output characteristic is unaffected by temperature over a wide thermal range.

2,848,603 Automatic Gain Control System —J. B. Schultz. Assignee: R. C. A. In an *a-g-c* circuit, a diode detector of a receiver is connected with the preceding amplifier stages in a manner that eliminates undesired direct current degeneration.

2,848,613 Transistor Blocking Oscillator—E. D. Green, M. G. Woolfson. Assignee: Westinghouse Electric Corporation. A blocking oscillator in which the pulse width of the output pulses can be adjusted by a time delay device connected between the collector and base of a transistor.

2,848,614 Regulated Power Supply—L. F. Lyons. Assignee: Bendix Aviation Corporation. Regulation of power from a converter is achieved by using a transistor configuration in conjunction with a saturable core transformer.

2,848,628 Transistor—Ring Counter—E. R. Altschul. Assignee: Hazeltine Research Inc. A transistorized ring counter which does not require multiple manual switching procedures when initially placed in operation.

2,848,653 Transistor Gating Circuit—L. W. Hussey, Assignee: Bell Tel. Labs. A transistorized current regulating device to be used as a protective element in conjunction with switching circuits employing gas tubes.

2,848,658 Light Responsive Circuit—A. V. Mitchell. Assignee: Tung-Sol Electric Inc. A semi-transistorized circuit for coupling a photoelectric device with a relay to be controlled by light incident on the photoelectric device.

2,848,665 Point-Contact Transistor and Method of Making Same—J. B. Little. Assignee: IBM. A transistor structure which facilitates the maintenance of a fixed electrode spacing.

2,848,711 Means for Providing Linear Indications of Shaft Rotations Greater Than Ninety Degrees—M. H. Rhodes. Assignee: Collins Radio Company. Apparatus for converting shaft rotation into electrical current which varies linearly as a function of said rotation up to approximately 110 degrees in either direction.

**August 26, 1958**

2,848,793 Method of Producing Diodes, Resistors, Rectifiers or the Like, or the Castings Thereof, and the Products—A. F. Pityo. Assignee: None. A method of welding together the casing sections of electrical devices without causing damage thereto because of excess heat.

2,849,341 Method of Making Semiconductor Devices—D. A. Jenny. Assignee: R. C. A. A method and apparatus for the production of alloy junction transistors which precludes individual handling of bodies of impurity yielding material, and which achieves the end product by fusing and alloying a molten mass of impurity yielding material into a selected portion of the surface of a semiconducting body.

2,849,342 Semiconductor Devices and Method of Making them—W. M. Webster. Assignee: R. C. A. A method for manufacturing a high frequency transistor in which the conductivity of the base-region surfaces.

2,849,343 Method of Manufacturing Semiconductor Bodies Having Adjoining Zones of Different Conductivity Properties — F. A. Kroger, J. C. Basart, J. Vanden Boomgaard. A method for producing the semiconductor body described, in which the concentration of foreign atoms of the lattice is controlled by doping the melt in the vapor phase.

2,849,539 Magnetic Core Circuits—H. H. Abbott. Assignee: Bell Tel. Labs. A signal generating circuit for use in an automatic telephone system, said circuit compressing a transistor switching device for periodically interrupting a subscriber line loop, and a magnetic core shift register for counting said interruptions.

2,849,611 Electrical Oscillator Circuit—R. P. Adams. Assignee: Minneapolis-Honeywell Regulator Company. A transistor oscillator circuit that is stable under widely varying ambient temperature conditions.

2,849,614 Electrical Inverter Circuit—G. H. Royer, R. L. Bright. Assignee: Westinghouse Electric Corporation. An electrical inverter circuit which uses a saturable magnetic core to produce an *a-c* output the time duration of which is dependent upon the magnitude of the direct input.

2,849,615 Circuit Arrangement for Converting a Low Voltage Into a High A.C. Voltage—D. F. Gustafson. Assignee: Contronics, Inc. A transistor oscillator using

a voltage transformer feedback system for converting low voltage *d-c* to high voltage *d-c*.

2,849,626 Monostable Circuit—O. D. Klapp. Assignee: Bell Tel. Labs. Networks that generate precisely controlled rectangular waveshapes in order to trigger other circuits to produce waveshapes in which the leading edge has a predetermined slope.

2,849,664 Semiconductor Diode — J. R. Beale. Assignee: North American Phillips Co., Inc. A method for manufacturing a high frequency diode having therein, minority carriers, the lifetime of which are low, in the order of one microsecond.

2,849,665 Ultra High Power Transistor—J. L. Boyer, A. P. Colaiaco. Assignee: Westinghouse Electric Corporation. A power transistor using a multiple-type electrode contact to one surface of a semiconductor in order to provide a high current carrying contact electrode.

2,849,673 Transistorized Inverters—R. M. Hubbard. Assignee: Boeing Airplane Company. A *d-c* voltage to square wave converter which effects complete separation of the timing control circuit from the power delivery circuit.

**September 2, 1958**

2,850,236 Polarity Sensitive Analogue Divider—D. H. Schaefer, D. G. Scargie Assignee: USA (Navy Dept). A polarity sensitive computing device for producing a quotient function of two input voltages.

2,850,412 Process for Producing Germanium Indium Alloyed Junctions—M. H. Dawson, E. Rasmanis. Assignee: Sylvania Electric Products. A process for effectively wetting germanium with indium in a hydrogen atmosphere at a pressure of 5 x $10^{-4}$ mm and at a temperature between 300°C and 700°C.

2,850,413 Process for Making Fused Junction Semiconductor Devices— M. F. Schmich. Assignee: Motorola Incorporated. In the fabrication of alloy junction transistors, a means of controlling the lateral flow and thickness of the alloying metal during its fusion to the semiconductor and to contain it in a selected area.

2,850,414 Method of Making Single Crystal Semiconductor Elements—M. Enometo. Assignee: None. A vacuum method of production.

2,850,444 Pulse Method of Etching Semiconductor Junction Devices—L. D. Armstrong, P. Kuznetzoff. Assignee: RCA. A method for etching germanium devices by subjecting them to a series of short high current pulses while they are in an electrolytic bath.

2,850,630 Transistor Multivibrator—T. A. Prugh. Assignee: USA (Dept of the Army). A free running, self starting, multivibrator the frequency of which is independent of transistor temperature; said device utilizing junction type transistors.

2,850,631 Frequency Modulating Transducer—R. M. Tillman. Assignee: Burroughs Corporation. A radio frequency, frequency modulating transducer for restricted mounting and severe operating conditions as a telemetering sub-carrier oscillator.

2,850,646 Transistor Bistable Circuit—W. E. Ingham. Assignee: Electric & Musical Industries Ltd. (England). A bistable circuit having a short switching period.

2,850,647 Exclusive or logical circuits—H. Fleisher. Assignee: IBM. An anticoincidence circuit for electronic computers.

2,850,648 Pulse Generating Circuit—G. Elliot. Assignee: General Dynamics Corporation. A high amplitude, long-duration output pulse-producing blocking oscillator which makes use of a periodically interrupted capacitor connection to the base of a transistor.

2,850,650 Transistor Current limiter—L. A. Meacham. Assignee: Bell Telephone Labs. A circuit that will produce a driving current having a relatively fixed peak to peak amplitude.

2,850,654 Controls for Electro Magnetic Coupling—R. L. Jaeschke. A transistorized control system for electrical coupling apparatus.

2,850,687 Semiconductor Devices—J. P. Hammes. Assignee: R.C.A. A potting medium comprising spherical pellets of metal or some other material imbedded in synthetic resin surrounds a semiconductor device and gives support thereto.

2,850,688 Semiconductor Circuit Elements—G. A. Silvey. Assignee: I.B.M. A zinc arsenide transistor having a conductivity directing impurity present in an amount of less than 1 per cent.

2,850,694 Current Supply Apparatus for Load Voltage Regulation—B. H. Hamilton. Assignee: Bell Telephone Labs. A transistorized apparatus for maintaining a constant load voltage over a predetermined range of load current, and over a wide range of ambient temperature.

2,850,695 Current Supply Apparatus for Load Voltage Regulation—J. D. Bishop. Assignee: Bell Telephone Labs. A current supply circuit for establishing a constant voltage of desired magnitude across a load.

2,850,699 Current Gain Measuring Circuit—G. M. Davidson, R. Gittleman. Assignee: American Bosch Arma Corporation. A method for measuring current gain in junction transistors using a null comparison technique in which the *d-c* bias voltage and currents can be varied independently with no effect on the *a-c* measurements and in which no capacitors are required under normal conditions.

2,850,703 Non Linear Terminations for Delay Lines—J. H. Vogelsong. Assignee: Bell Telephone Labs. A nonlinear terminating circuit for a pulsed electrical delay line which matches the characteristic impedance of the line over almost all of the pulse interval.

**September 9, 1958**

2,851,220 Transistor Counting Circuit—R. E. Kimes. Assignee: Beckman Instruments, Inc. A ring counter on which the indicating stage is in the low current conducting state, and the non-indicating stage is in the high current conducting state; said arrangement being embodied in a counter which will operate at high rates of 100 *kc* and over.

2,851,341 Method and Equipment for Growing Crystals—S. I. Weiss. Assignee: None. Apparatus for growing semiconductor crystals, said apparatus providing vibration and rotation of the crystal at desired frequency and withdraw of the crystal from the melt without the need of tapes or cords.

2,851,342 Preparation of Single Crystals of Silicon—S. E. Bradshaw, H. Weald, A. I. Mlavsky. Assignee: The General Electric Company Limited. A single crystal growing process consisting of withdrawing a seed from a melt, said melt being maintained at a temperature of at least 30°C above the melting point of silicon, the entire process taking place at a pressure of not more than $10^{-3}$ mm of mercury.

2,851,405 Titanate Rectifiers—J. J. Dynon, E. B. Saubestre. Assignee: Sylvania Electric Products, Inc. A method of manufacturing titanate rectifiers which includes preparation of a titanate pellet and firing thereof in a reducing atmosphere at temperatures between 2000°F and 2600°F, cooling the vitrified pellet in the same atmosphere, and forming a barrier layer thereon by electrodeposition of lead or manganese dioxide.

2,851,540 Transistor Signal Translating Circuit—G. E. Theriault. Assignee: RCA. A circuit designed for use with variable capacity type phonograph pick-ups.

2,851,542 Transistor Signal Amplifier Circuits—R. D. Lohman. Assignee: RCA. An amplifier which allows stable push-pull class B operation with semiconductor devices having a wide variety of operating characteristics but which does not introduce crossover distortion.

2,851,594 Frequency Converter Using Four-Zone Transistor as Oscillator-Mixer—E. W. Herold. Assignee: RCA. A frequency converter circuit utilizing a single four zone transistor for developing a local oscillator signal and mixing it with an applied carrier to produce a desired beat frequency signal.

2,851,604 Signal Translating Apparatus—G. L. Clapper. Assignee: IBM. A stable, high speed square-wave-output oscillator circuit.

2,851,615 Semiconductor Devices and Systems—G. C. Sziklai, G. B. Herzog. Assignee: RCA. A multielectrode semiconductor device including therein means for establishing a rotating electric field, said device being designed to accomplish complex electrical functions such as are found in color television systems.

2,851,638 Voltage Magnitude Comparison Circuit—R. C. Wittenberg, H. Sandler. Assignee: Reeves Instrument Corporation. A circuit for indicating when an applied voltage has exceeded a predetermined magnitude regardless of the polarity of the applied voltage, said circuit utilizing a transistor amplifier in conjunction with a glow discharge tube indicator.

**September 16, 1958**

2,852,420 Method of Manufacturing Semiconductor Crystals—R. G. Pohl. Assignee: The Rauland Corporation. A method of production for junction transistors which includes forming a melt of semiconductor, and a donor and acceptor modifier, said donor modifier exhibiting a variation in segregation factor with changes in interface temperature gradient which is different from the segregation factor changes exhibited by the acceptor modifier.

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| A Transistorized Stereo Phono Preamplifier | Audio June 1960 | Complete circuit and mechanical details described and discussed. | W. B. Bernard |
| Principles of Thermoelectric Devices | Br Jl Appl Phys June 1960 | Discussion of coefficient of performance for refrigeration, efficiency of generation, thermoelectric properties of semiconductors, semiconductor compounds and alloys, and small-scale thermoelectric devices. | H. J. Goldsmid |
| The Brushless Synchronous Motor | Elecl Mfg June 1960 | The advent of the high-current silicon controlled rectifier makes the brushless synchronous motor possible in a system which eliminates all sliding and mechanical contacts. | G. M. Rosenberry, Jr. |
| Materials and Techniques for Microminiaturization-2 | Elecl Mfg June 1960 | Covered in this installment are: capacitors, diodes and transistors, protective coverings, inductors; also current advances in integrated solid circuitry. | P. J. Franklin<br>E. F. Horsey |
| Magamp Regulator for DC- to DC Converters | Elecnc Design June 8 1960 | Design for an efficient lightweight unit that will provide ±2% regulation over a wide range of input voltages and loads. | B. Berman |
| Synchronous Switches, Their Many Forms and How to Use Them | Elecnc Design June 8 1960 | Operation and applications of synchronous switches. Passive vs active switches, degree of excitation, etc. using tubes and semiconductors also discussed. | R. Goldstein |
| Digital Data Transmission by Wire | Elecnc Design June 8 1960 | Various phases are discussed of operation under conditions presenting unique problems using amplitude modulation techniques. | C. R. Fisher |
| Solving Thermistor Problems Without Nomographs | Elecnc Design June 22 1960 | Use of asymptatic plots makes design engineers independent of nomographs. | J. P. Cummings |
| Tunnel Diode Relaxation Oscillators | Elecnc Design June 22 1960 | Design information plus experimental results for astable, monostable, and bistable tunnel diode relaxation oscillators. | C. M. Barrack<br>M. C. Watkins |
| A Miniature Transistorized Echo-Sounder | Elecnc Engg (Br) June 1960 | Development and design features of an echo sounder for use in depths from 2.5 to 32 fathoms. | R. N. Gatehouse |
| A Passive Waveform Shaping Circuit | Elecnc Engg (Br) June 1960 | The combination of an inductance together with one or more suitable diodes produce a simple circuit capable of performing a number of diverse functions in waveform shaping or pulse delay circuits. | M. J. Wright |
| The Design of Optical Digital Instruments | Elecnc Engg (Br) June 1960 | Various design considerations are first discussed; some low resolution instruments are then described; finally problems associated with high resolution units are considered. | I. R. Young |
| Semiconducting Indium Compounds | Elecnc Engg (Br) June 1960 | Preparation and purity, binding energies, electronic mobilities, tertiary compounds, and applications are discussed. | (No Author) |
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| Digital Voltmeter Logic | Elecnc Equip Engg June 1960 | Transistor circuitry and logic required to perform analog to digital conversion for decimal readout, and to display automatically the polarity of the voltage being measured. | R. A. Allen |
| Rating Transistors for Pulse Operation | Elecnc Equip Engg June 1960 | Curves provide method of rating transistor for pulse operation under various conditions of power, dissipation, and duty cycle, in relation to pulse repetition rate and thermal time constant of the transistor. | H. L. Morgan |
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| Demodulators for Linear Differential Transformers | Electronics June 3 1960 | Applications of linear variable differential transformers require demodulation of the *a-c* output. Demodulation techniques are summarized. | J. Lipshutz<br>M. Aronow |
| Analytical Design of Transistor Push-Pull Amplifiers | Electronics June 10, 1960 | Using a mathematical analysis of collector waveform and equivalent circuits, expressions for making an exact determintion of gain, efficiency, and bias circuit design are derived. | R. H. Riggs |
| Novel Design Peak Voltmeter | Electronics June 17, 1960 | Auxiliary flip-flop compares input pulse with voltage already on integrating capacitor. Flip-flop then automatically adjusts capacitor charge to match peak voltage of input. | R. P. MacKenzie |
| Transistorized Sound Level Meter | Electronics June 17, 1960 | Development and description of sound level meter with high input impedance circuit. | W. V. Richings<br>B. J. White |
| Generating High-Quality Characters and Symbols | Electronics June 17, 1960 | Solid-state character generator using transistors is described. | J. K. Moore<br>M. Kronenberg |
| Converting Oscilloscopes for Fast Rise Time Sampling | Electronics June 24, 1960 | Transistorized attachment for conventional oscilloscopes can resolve pulse rise times of 1/3 namosecond with repetition rates of up to 50 kc. | J. J. Amodei |
| Tunnel Diode Logic Circuits | Electronics June 24, 1960 | Diode current-voltage characteristics, modes of operation, and effect of circuit component tolerances are examined. Tolerance equations are derived. | W. F. Chow |
| Tunnel Diodes | Elecnc Tech (Br) June 1960 | Principles of operation, characteristics, equivalent circuit, and applications. | G. N. Roberts |
| The Junction Transistor | Elecnc Tech (Br) June 1960 | The grounded base amplifier is derived as a negative feedback version of the grounded emitter circuit, taking the latter as basic. | M. K. Achuthar |
| A Transistorized Portable Television Receiver | IRE Tr B & TV Rec May 1960 | Description of tuner, i-f amplifier, sound system, sync separator and noise switch. | A. R. Curll |

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|---|---|---|---|
| A Transistor TV I-F Amplifier | IRE Tr B & TV Rec May 1960 | Design requirements, emitter follower, detector and final *i-f* amplifier, automatic gain control, and neutralization are discussed. | J. G. Humphrey |
| Designing Solar Power Supplies for Transistorized Radio Receivers | IRE Tr B & TV Rec May 1960 | Discussion of basic characteristics of solar cells, equivalent circuit of solar cell assembly, rechargeable battery and transistor radio, and charging action therein. | J. Kalman |
| The Video Processing Circuits for an All-Transistor Television Receiver | IRE Tr B & TV Rec May 1960 | Description of circuits which process the detected video signal and extract from it the various subsignals. | C. D. Simmons<br>C. R. Gray |
| Transistorized Vertical Scan System for Magnetic Deflection | IRE Tr B & TV Rec May 1960 | A transistorized vertical deflection system has been developed to scan a 90°, 14-inch picture tube at 14KV accelerating voltage. | F. L. Abboud |
| Linearization of Transistorized Vertical Deflection System | IRE Tr B & TV Rec May 1960 | Study of the linearity problems associated with a two-transistor vertical deflection system. | R. B. Ashley |
| Transient Response of Variable Capacitance Diodes | IRE Tr Comp Parts June 1960 | A solution for the transient response of a reverse biased diode by a step function (voltage) may be found by considering the junction essentially a voltage variable capacitnce. | D. Schulz |
| Power Sources Designed for Space | IRE Tr Mil Elecns June 1960 | Conversion systems employing chemical, solar, and nuclear energies are described, and their prospect for further improvement discussed. | W. Shorr<br>D. Linden<br>A. F. Daniel |
| Preparation of Large Area Single-Crystal Cuprous Oxide | Jl Appd Physics June 1960 | Large area single crystals of $Cu_2O$ were grown by the process of high temperature annealing. | R. S. Toth<br>R. Kilkson<br>D. Trivich |
| Properties of *p*-Type GaAs Prepared by Copper Diffusion | Jl Appd Physics June 1960 | Conversion of *n*-type GaAs to *p*-type was accomplished by the inward diffusion of copper from the crystal surface. | F. D. Rosi<br>D. Meyerhoffer<br>R. V. Jensen |
| Photoeffects in Nonuniformly Irradiated *p-n* Junctions | Jl Appd Physics June 1960 | A theoretical basis is provided for the interpretation of photoeffects observed in nonuniformly irradiated *p-n* junctions. | G. Lucovsky |
| Electron Probe Measurements of Evaporated Metal Films | Jl Appd Physics June 1960 | Calibration curves of X-ray intensity vs specimen thickness have been prepared for the electron probe microanalyzer by using evaporated films of Cr, Mn, Zn, and Au in the 0-5000 A range. | W. E. Sweeney, Jr.<br>R. E. Seebold<br>L. S. Birks |
| On the Neutron Bombardment Reduction of Transistor Current Gain | Jl Appd Physics June 1960 | Detailed measurements of the fast neutron, and gamma-ray bombardment behavior of germanium alloy-transistor current-gain have been obtained concurrent with exposure. | J. W. Easley |
| Vapor - Deposited Single - Crystal Germanium | Jl Appd Physics June 1960 | Germanium layers have been formed on single-crystal Ge substrates by the thermal decomposition of $GeI_2$. | R. P. Ruth<br>J. C. Marinace<br>W. C. Dunlap, Jr. |
| Production and Properties of Thin Layers of Indium Antimonide | Jl Appd Physics June 1960 | A new method of producing thin layers of indium antimonide is described. This consists of suddenly squashing a drop of molten indium antimonide between two optical flats and allowing it to cool. | G. Bate<br>K. N. R. Taylor |
| *p*-Layers on Vacuum Heated Siliicons | Jl Appd Physics June 1960 | It has been established that when silicon is heated above 1300°K in a borosilicate vacuum system, from $10^{11}$ to $10^{15}$ acceptors per $cm^2$ are normally added to the silicon surface. | F. G. Allen<br>T. M. Buck<br>J. T. Law |
| Photoemission in the Photovoltaic Effect in Cadmium Sulfide Crystals | Jl Appd Physics June 1960 | A study has been made of the photovoltaic effect in Cu-CdS cells and related systems associated with undiffused metal-semiconductor junctions. | R. Williams<br>R. H. Bube |
| Transport of Noise at Microwave Frequencies through a Space-Charge Limited Diode | Jl Appd Physics June 1960 | The magnitude and variation with distance of the so-called beam noise invariants is shown for a range of diode operating conditions. | W. E. Vivian |
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| Intervalley Noise | Jl Appd Physics June 1960 | A theory is developed for the spectrum of electrical noise due to electron transitions between several quasi-isolated groups of states. | P. J. Price |
| Avalanche Carrier Multiplication in Junction Transistors and its Implications in Circuit Design | Jl Brit IRE June 1960 | Avalanche multiplication may be used to obtain useful device characteristics and circuits. Methods of measurements are outlined. | M. L. N. Forrest |
| The Diffused Shot-Melting Technique for Making Germanium and Silicon *p-n* Junction Devices | Jl Electrochem Soc June 1960 | This involves the melting and resolidifying of a piece of semiconductor on a wafer of the same material to form a single crystal boundary region, and the subsequent diffusion of impurities across the interface. | J. A. Lesk |
| Preparation and Properties of AlSb-GaSb Solid Solution Alloys | Jl Electrochem Soc June 1960 | Ingots of the quasi-binary GaSb-AlSb alloy were prepared by progressive casting and zone casting at various rates of crystallization. | G. F. Miller<br>H. L. Goering<br>R. C. Himes |
| On the Physical Characteristics and Chemical Composition of Electroluminescent Phosphors | Jl Electrochem Soc June 1960 | The experimental results at progressive stages of etching are interpreted in terms of an inefficient surface layer and of decreased particle size after etching. | P. Goldberg<br>A. Faria |
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| Equipment for the Encapsulation of Semiconductor Devices | Jl Scient Insts (Br) June 1960 | A hydraulically operated ram carries the semiconductor device and its envelope, loosely assembled, into a Pyrex chamber where they are processed. | R. D. Knight |
| Design of Cooling Fins for Silicon Power Rectifiers | Mullard Tech Comm June 1960 | A practical design procedure is given for plane cooling fins for silicon power rectifiers, both for single rectifiers and for stacks. | J. Tuley |
| Switching Times for Alloy Junction Transistors | Mullard Tech Comm June 1960 | An equivalent circuit is used to calculate switching times in a few simple examples, and methods of measuring parameters are described. | P. James<br>A. F. Newell |

| TITLE | PUBLICATION | CONDENSED SUMMARY | AUTHORS |
|---|---|---|---|
| P.N Luminescence and Photovoltaic Effects in GaP | Philips Res Repts June 1960 | Crystals made at low phosphorous pressure mainly showed *n*-conductivity. Crystals with *p*-conductivity were obtained by heating at high phosphorous pressure or by doping with Zn. | H. G. Grimmeiss<br>H. Koelmans |
| Measurement of Decay Times of Excess Carriers in Semiconductors, Excited by X-Ray Pulses | Philips Res Repts June 1960 | A method for the measurement of transient decay times of excess carrier concentrations in homogeneous semiconductors is described. | J. A. W. vander Does de Bye |
| Fluorescence of Some Activated ZnS Phosphors | Philips Res Repts June 1960 | Several series of ZnS phosphors were prepared in $H_2S$ atmosphere at 1150-1200°C. | W. van Gool<br>A. P. Cleiren<br>H. J. M. Heiligers |
| Self-Activated and Cu-Activated Fluorescence of ZnS | Philips Res Repts June 1960 | Experiments presenting additional data on the theory of ZnS activated with Cu. Study of the difference between the blue Cu emission and the blue self-activated emission of ZnS. | W. van Gool<br>A. P. Cleiren |
| Excitation Spectra of Vanadium Activated Zinc and Cadmium Sulphide and Selenide Phosphors | Philips Res Repts June 1960 | Excitation spectra were measured for the 2u fluorescence band of vanadium activated zinc and cadmium sulphide and selenide phosphors. | G. Meijer<br>M. Avinor |
| A Simple Circuit for a Light Source of Constant Intensity | Philips Tech Rev June 1960 | This article describes a simple circuit in which a cadmium-sulphide photoresistor is used to keep the emission of an incandescent lamp at constant intensity. | H. van Suchtelen |
| Crystal Potential and Energy Bands of Semiconductors. III. Self Consistent Calculations for Silicon | Physical Review June 1, 1960 | An approximately self-consistent potential is constructed for Si from a superposition of free-atom core and a sampling of crystal valence band charge densities. | L. Kleinman<br>J. C. Phillips |
| Effect of High Pressure on Some Hot Electron Phenomena in *n*-type Silicon | Physical Review June 15, 1960 | The pressure dependence of the current density vs electric field characteristic for *n*-type germanium at 297°K has been measured to a maximum pressure of 30,000 kg/cm² and to a maximum field of 10,00 v/cm. | A. G. Chynoweth<br>R. A. Logan |
| Internal Field Emission at Narrow p-n Junctions in Indium Antimonide | Physical Review June 15, 1960 | An experimental study has been made of the field and temperature dependence of internal field emission in narrow *p-n* junctions in indium antimonide. | H. Hasegawa |
| Spin-Lattice Relaxation of Shallow Donor States in Ge and Si through a Direct Phonon Process | Physical Review June 1, 1960 | The many-valley character of the conduction band edge of germanium and silicon causes an anistropy of the *g* shift and the deformation potential for the conduction electrons. | S. H. Koenig<br>M. I. Nathan<br>W. Paul<br>A. C. Smith |
| The Characteristics and Protection of Semiconductor Rectifiers | Proc IEE (Br) Part A Power Engg June 1960 | This paper describes probable sphere of application. Basic characteristics are discussed with special test methods. Operating conditions examined. | D. B. Corbyn<br>N. L. Potter |
| The Application of Power Transistors to the Operation of Gas-Discharge Lamps form D. C. Supplies | Proc IEE (Br) Part A Power Engg June 1960 | The operation of fluorescent tubes on high frequency supplies (up to 20 kc) is considered. Characteristics of sine wave and square wave transistor inverters are discussed. | I. F. Davies<br>D. Dunthorne |
| Microminiature Multichannel Pulse Position-Modulation System Incorporating Transistor-Magnetic-Core Circuitry | RCA Review June 1960 | An experimental five-channel time division multiplex system has been built incorporating a microminiature transistor-core ring counter for both the transmitter modulator and receiver sampler. | K. Kihn<br>R. J. Klensch<br>A. H. Simon |
| Absolute Spectral Response Characteristics of Photosensitive Devices | RCA Review June 1960 | Date are presented comparing absolute response characteristics associated with the various commercial type photocathodes. | R. W. Engstrom |
| Determination of the Impurity Distribution in Junction Diodes from Capacitance-Voltage Measurements | RCA Review June 1960 | A method for the measurement of impurity distributions to the required degree of accuracy is described. | J. Hillibrand<br>R. D. Gold |
| Transistorized Precision Ratemeter | Rev Scient Insts June 1960 | A linear ratemeter based on a special circuit with a saturated-core blocking oscillator is described. | G. Gianelli<br>V. Mandl |
| Temperature Control of Silicon Solar Cells in Space Environment | Semiconductor Prods June 1960 | Optical coatings have been developed which notably reduce the temperature with corresponding increase of power output. | W. Luft<br>H. Nash |
| Esaki or Tunnel Diodes (Part II) | Semiconductor Prods June 1960 | Physical effects which produce electrical characteristics of tunnel diodes; also design and construction of these devices. | W. W. Gärtner |
| Applications of Transistors to Video Equipment (Part II) | Semiconductor Prods June 1960 | Sync signal generator is described in this installment. Includes block diagram and waveform discussion. | K. Hiwatashi<br>Y. Fujimura<br>K. Suzuki<br>N. Mii |
| Transistorized Automobile Receivers Employing Drift Transistors | Semiconductor Prods June 1960 | This article describes various 5-stage auto-receiver *r-f*, converter, and i-f stages, using drift transistors. | R. A. Santilli<br>C. F. Wheatley |
| The Influence of Impurities on the Strong-Field Effect in Selenium Rectifiers | Sov Phys Sol State May 1960 | The authors conclude that the inverse branch of the volt-ampere characteristics of selenium rectifiers depends primarily on the purity of the materials used (selenium, sulfur, cadmium). | G. B. Abdullaev<br>M. G. Aliev<br>I. Kh. Geller |
| The Effect of Tin and Bismuth Impurities on the Thermal Conductivity of Selenium | Sov Phys Sol State May 1960 | The thermal conductivity of each sample was measured several times in a stationary thermal field using a "plane" method, and its mean value was calculated. | N. A. Aliev<br>N. I. Abragimov |
| An Investigation of P-N Junctions at High Current Densities | Sov Phys Sol State May 1960 | Results of an experimental investigation of the transition blocking process, the diffusion voltage, and the conductivity of the low impurity region in relation to the forward current value in fused In-Ge *p-n* junctions. | Yu K. Barsukov |
| Effect of Deformation of the Hole Energy Spectrum of Germanium and Silicon | Sov Phys Sol State May 1960 | The effect of deformation on the electrical properties of germanium and silicon in two limiting cases are briefly considered: low-temperature and high-temperature. | G. E. Pikus<br>G. L. Bir |
| Luminescence of Impurity Centers. I. | Sov Phys Sol State May 1960 | A relation between changes in elastic constants and the deviation of the absorption and luminescence spectra from mirror symmetry; also from a gaussian shape. | A. M. Ratner<br>G. E. Zillberman |
| Hall Probes of Indium Arsenide for Measurement of Magnetic-Field Intensities | Sov Phys Sol State May 1960 | The present paper reports the results obtained during development of Hall probes for magnetic field measurements based on indium arsenide. | N. V. Zotova<br>D. N. Nasledov |

| TITLE | PUBLICATION | CONDENSED SUMMARY | AUTHORS |
|---|---|---|---|
| The Effect of Surface Treatment on the Spectral Conductivity | Sov Phys Sol State May 1960 | Surface treatments and consequent changes of surface recombination rates alter essentially the magnitude and the form of the spectral photoconductivity response of *p*-type silicon. | V. A. Petrusevich |
| An Energy Barrier Between Slow Surface Traps and the Bulk of Germanium and Silicon | Sov Phys Sol State May 1960 | The author investigated variations of the contact potential of germanium and silicon after illumination of their surfaces. | I. I. Abkevich |
| Luminescence of Impurity Centers. II | Sov Phys Sol State May 1960 | The probability of thermal transitions between discrete levels associated with the presence of an impurity center is calculated. | T. A. Kontorova |
| On the Question of Fusion of Ge and Si | Sov Phys Sol State May 1960 | If the initial substance possesses semiconducting properties, then fusion may be accompanied by transition into a metallic state. | S. M. Ryvkin<br>B. M. Konovalenko |
| Dependence of the Induced Conductivity in Cadmium Sulfide on the Energy of Exciting Electrons | Sov Phys Sol State May 1960 | Certain quantitative differences between values obtained by other workers and the value of L of the CdS monocrystals used can be satisfactorily explained. | S. G. Kalashnikov<br>K. P. Tissen |
| The Cross Section of Capture of Electrons and Holes by Atoms of Nickel in Germanium | Sov Phys Sol State May 1960 | The present paper deals with the results of similar measurements in *n*-type germanium, and with the absolute capture cross sections of nickel atoms for holes and electrons in germanium. | A. H. Ratner |
| Emission Properties of Germanium Treated in Cesium Vapor | Sov Phys Sol State May 1960 | The paper reports an experimental investigation of thermionic, photoelectric, and secondary electron emission of *n*-type germanium monocrystals, and of germanium films produced by evaporation in vacuo in cesium vapor. | V. G. Bol'shov<br>et al |
| Determination of the Ratio of the Electron and Hole Capture Cross Sections of Copper Atoms in Germanium | Sov Phys Sol State May 1960 | The present paper reports the results obtained using a previously described method, for copper atoms in germanium. | A. Konstantinesku |
| A Possible Method of Determining the Ratio of Capture Cross Sections of Recombination Centers in Semiconductors | Sov Phys Sol State May 1960 | The advantage of the method described lies in the avoidance of the difficult measurements of the life time, the injection level, and the recombination center concentration. | S. G. Kalashnikov<br>K. Konstantinesku |
| Chemical Considerations in High Temperature Thermoelectric Power Developments | US Gov Res Repts June 17, 1960 LC \$6.30 PB 145076 | No Abstract. | |
| Research on Recombination Processes in Semiconductor | US Gov Res Repts June 17, 1960 LC \$3.30 PB 145039 | A special cryostat and optical system were designed and built. The system is transportable and entirely non-magnetic. | Compagnie Generale de Telegraphie Sans Fil France |
| Investigations of Surface Properties of Silicon and other Semiconductors, Phase I and II | US Gov Res Repts June 17, 1960 LC \$4.80 PB 145624 | A comparison has been made of the structure of the surface of a bismuth telluride crystal produced by cleaving, and a similar surface prepared by the bombarding and annealing technique. | H. E. Farnsworth<br>D. Haneman<br>et al |
| Organic Semiconductors | US Gov Res Repts June 17, 1960 OTS \$1.25 PB 161459 | A theoretical study was made of the various mechanisms and reactions which would lead to organic semiconductors. | D. E. Laskowski<br>E. H. Tompkins<br>O. W. Adams |
| Theoretical and Experimental Research in Thermoelectricity | US Gov Res Repts June 17, 1960 OTS \$3.00 PB 161468 | Techniques and equipment for growing single crystals of $Bi_2Te_3$ Preparation of Hg-CdTe alloys with a general discussion of measurements on this material. | Electronic Syst. Lab.<br>Mass. Inst. of Tech. |
| Research Directed toward the Study, Analysis, and Design of Transistor Circuits | US Gov Res Repts June 17, 1960 | This report is concerned with the investigation of the high current mode of transistor operation first described by Thornton and Simmons (*IRE Trans Ed-5 Jan '58*). | A. W. Carlson |
| Shunt-Peaked Transistor Amplifiers | US Gov Res Repts June 17, 1960 LC \$4.80 PB 145696 | Analysis, comparison, and design of broad-banded, low-pass transistor amplifiers. | R. S. Pepper<br>D. O. Pederson |
| A Note on Simplified Transistor Equivalent Circuits | US Gov Res Repts June 17, 1960 LC \$3.30 PB 145496 | With these simpler circuits a great deal of modern network technology can be easily applied with physical insight to the study and design of transistor circuitry. | D. O. Pederson |
| Application of Transistors to Electronic Counting Equipment | US Gov Res Repts June 17, 1960 LC \$6.30 PB 145263 | Design and study of junction transistor binaries; and in the construction and testing of a decade counter. | H. Crisholm |
| Application of Transistors to Electronic Counting Equipment | US Gov Res Repts June 17, 1960 LC \$4.80 PB 145264 | General study includes the theory of the transistor device, its various characteristics, circuits, applications, and switching circuits. | R. E. Kimes |
| Junction Transistor Measurements and Standards | US Gov Res Repts June 17, 1960 OTS \$0.75 PB 161469 | Report covers the basic measurements required on most transistors, and specific techniques and circuits for VHF and UHF devices. Sample transistor spec is given to demonstrate acceptance electrical tests. | B. Reich |
| The Development and Engineering Tests of a Transistorized High Voltage Power Supply for Infrared Binoculars | US Gov Res Repts June 17, 1960 LC \$4.80 PB 145276 | Tests of a 120 kv, *d-c* power supply for use as the source of high voltage for operating two type 6929 infared image tubes. | I. Kessler |
| Active Diodes of the PNPN Type | US Gov Res Repts June 17, 1960 LC \$10.80 PB 145523 | Work done on "Shorted-Emitters". A number of types are described in detail. Results of doping with gold to reduce lifetime. | General Electric Co. |

# CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

MANUFACTURERS

AEG— Allgemeine Elekticitats-Gesellschaft
AEI— Associated Electrical Industries, Ltd.
AMP— Amperex Electronic Corp.
BEN— Bendix Corp.
BER— Berkshire Labs
BOG— Bogue Electric Mfg. Co.
BOM— Bomac Labs
BRA— Bradley Semiconductor Corp.
CBS— CBS Electronics
CDC— Continental Device Corp.
COD— Computer Diode Corp.
COL— Columbus Electronics Corp.
CTP— Clevite Transistor Products, Inc.
CSF— Compagnie Generale de T.S.F.
DEL— Delco Radio
DIC— Dickson Electronics Corp.
EEVB— English Electric Valve Co., Ltd.
ERI— Erie Resistor Corp.
FAN— Fansteel Metallurgical Corp.
FERB— Ferranti Ltd.
FSC— Fairchild Semiconductor Corp.
GAH— Gahagan, Inc.
GECB— General Electric Co., Ltd.
GE— General Electric Company, Semiconductor Div.
GELC— Canadian General Electric Co.
GIC— General Instrument Corp.
GTC— General Transistor Corp.
HAFO— Institutet for Halvedarforskning
HSD— Hoffman Semiconductor Division
HITJ— Hitachi Ltd., Mushashi Works
HUG— Hughes Products Division
INRB— International Rectifier Co., Ltd.
INRC— International Rectifier Corp.
IRC— International Resistance Co.
ITT— International Tel. & Tel. Corp.
KEM— Kemtron Electron Products, Inc.
MATJ— P. R. Mallory & Co., Inc.
MAL— Matushita Electronics Corp., Takatsuki, Osaka, Japan
MIC— Microwave Associates, Inc.
MIFI— Microfarad
MOT— Motorola, Inc.
MUL— Mullard, Ltd.
NAE— North American Electronics
NPC— Nucleonic Products Co., Inc.
OHI— Ohio Semiconductor Inc.
OHM— Ohmite Manufacturing Co.
PHI— Philco Corp. Lansdale Div., Semiconductor Operations
PHIN— Philips Gloeilampenfabrieken, Eindhoven, Netherlands
PLEB— The Plessey Co.
PSI— Pacific Semiconductors, Inc.
QSC— International Diode Corp.
RADF— La Radiotechnique, Div. Tubes Electroniques
RAY— Raytheon Company
RCA— Radio Corporation of America, Semiconductor Div.
RHE— Rheem Semiconductor Corp.
ROSG— Dr. Ing. Rudolph Rost
SAR— Sarkes Tarzian, Inc., Rectifier Division
SCN— Semicon, Inc.
SEM— Semi-Elements Inc.
SIE— Siemens & Halske Aktiengesellschaft
SIL— Silicon Transistor Corp.
SOIF— Societe Industrial de Liaisons, Paris 8e, France
SONY— Sony Corp.
SSD— Sperry Semiconductor Division
SSP— Solid State Products, Inc.
STC— Shockley Transistor Corp.
STCB— Standard Telephone & Cables, Ltd.
SYL— Sylvania Electric Products, Inc.
SYN— Syntron Co.
TEX— Texas Research Assoc.
TFKG— Telefunken, Ltd.
TI— Texas Instruments Incorporated
TKD— Tekade, Nurnberg, Germany
TOK— Tokyo Tsushin Kogyo, Ltd.
TRA— Transitron Electronic Corp.
TUN— Tung-Sol Electric, Inc.
TSC— Trans-Sil Corp.
UCI— United Components
USD— United States Dynamics Corp.
USS— U. S. Semiconductor Products, Inc.
VIC— Vickers Inc.
WEC— Western Electric Co.
WEST— Westinghouse Electric Corp.

## CHARACTERISTICS CHART OF SILICON ZENER or AVALANCHE DIODES

| TYPE NO. | Zener or Avalanche Voltage Range MIN. $E_{b1}$ (volts) | MAX. $E_{b2}$ (volts) | @ $I_z$ (ma) | Dynamic Impedance Z (ohms) | @ $I_z$ (ma) | MAX. DISS. (mw) | TEMP. CO-EF-FICIENT %/°C | MFR. (See code at start of chart) |
|---|---|---|---|---|---|---|---|---|
| GLZ7.5BC-A | 7.1 | 7.9 | 8.3 | 8.0 | 8.3 | 250 | .045 | USS |
| GLZ8.2BC-A | 7.8 | 8.6 | 7.6 | 9.0 | 7.6 | 250 | .048 | USS |
| GLZ9.1BC-A | 8.6 | 9.6 | 6.9 | 10 | 6.9 | 250 | .051 | USS |
| GLZ10BC-A | 9.5 | 10.5 | 6.3 | 11 | 6.3 | 250 | .055 | USS |
| GLZ11BD-A | 10.4 | 11.6 | 5.7 | 13 | 5.7 | 250 | .060 | USS |
| GLZ12BC-A | 11.4 | 12.6 | 5.2 | 15 | 5.2 | 250 | .065 | USS |
| GLZ13BD-A | 12.3 | 13.7 | 4.8 | 18 | 4.8 | 250 | .065 | USS |
| GLZ14BB-A | 13.3 | 14.7 | 4.5 | 20 | 4.5 | 250 | .070 | USS |
| GLZ15BD-A | 14.2 | 15.8 | 4.2 | 22 | 4.2 | 250 | .070 | USS |
| GLZ16BC-A | 15.1 | 16.9 | 3.9 | 24 | 3.9 | 250 | .070 | USS |
| GLZ17BB-A | 16.1 | 17.9 | 3.7 | 26 | 3.7 | 250 | .075 | USS |
| GLZ18BC-A | 17.1 | 18.9 | 3.5 | 28 | 3.5 | 250 | .075 | USS |
| GLZ19BD-A | 18 | 20 | 3.3 | 30 | 3.3 | 250 | .075 | USS |
| GLZ20BC-A | 19 | 21 | 3.1 | 33 | 3.1 | 250 | .075 | USS |
| GLZ22BC-A | 20.9 | 23.1 | 2.8 | 40 | 2.8 | 250 | .080 | USS |
| GLZ24BD-A | 22.8 | 25.2 | 2.6 | 46 | 2.6 | 250 | .080 | USS |
| GLZ25BB-A | 23.7 | 26.3 | 2.5 | 50 | 2.5 | 250 | .080 | USS |
| GLZ27BC-A | 25.6 | 28.4 | 2.3 | 58 | 2.3 | 250 | .085 | USS |
| GLZ30BC-A | 28.5 | 31.5 | 2.1 | 70 | 2.1 | 250 | .085 | USS |
| GLZ33BC-A | 31.3 | 34.7 | 1.9 | 85 | 1.9 | 250 | .085 | USS |
| GLZ36BC-A | 34.2 | 37.8 | 1.7 | 100 | 1.7 | 250 | .085 | USS |
| GLZ43BC-A | 40.8 | 45.2 | 1.5 | 140 | 1.5 | 250 | .090 | USS |
| GLZ45BB-A | 42.7 | 47.3 | 1.4 | 150 | 1.4 | 250 | .090 | USS |
| GLZ47BC-A | 44.6 | 49.4 | 1.3 | 160 | 1.3 | 250 | .090 | USS |
| GLZ50BB-A | 47.5 | 52.5 | 1.2 | 180 | 1.2 | 250 | .090 | USS |
| GLZ52BB-A | 49.4 | 54.6 | 1.2 | 200 | 1.2 | 250 | .090 | USS |
| GLZ56BC-A | 53.2 | 58.8 | 1.1 | 230 | 1.1 | 250 | .090 | USS |
| GLZ62BC-A | 58.9 | 65.1 | 1.0 | 290 | 1.0 | 250 | .090 | USS |
| GLZ68BC-A | 64.6 | 71.4 | .92 | 350 | .92 | 250 | .090 | USS |
| GLZ75BC-A | 71.2 | 78.8 | .83 | 450 | .83 | 250 | .090 | USS |
| GLZ82BC-A | 77.9 | 86.1 | .76 | 550 | .76 | 250 | .090 | USS |
| GLZ91BC-A | 86.4 | 95.6 | .69 | 700 | .69 | 250 | .090 | USS |
| GLZ100BC-A | 95 | 105 | .63 | 900 | .63 | 250 | .090 | USS |
| SZ15B Ø | 13.2 | 16.5 | 100 | 3.0 | 100 | 25W | .07 | GECB |
| SZ18B Ø | 16.2 | 19.9 | 100 | 3.0 | 100 | 25W | .08 | GECB |
| SZ22B Ø | 19.7 | 24.4 | 100 | 3.0 | 100 | 25W | .08 | GECB |
| SZ27B Ø | 24.2 | 29.8 | 100 | 3.0 | 100 | 25W | .08 | GECB |
| SZ33B Ø | 29.6 | 36.3 | 100 | 4.0 | 100 | 25W | .08 | GECB |

Ø Revised specifications

Δ Also available with plus or minus 5% tolerance

Ø Double ended anode type

# CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

| TYPE NO. | CLASSIFI-CATION | DESCRIPTION | MFR. |
|---|---|---|---|
| 1N53D | 1 | High temperature Ka-band Mixer (Coaxial) | SYL |
| 1N53RD | 1 | High temperature Ka-band Mixer (Coaxial) | SYL |
| 1N2928 | 10 | Si.; Ip-.47ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2928A | 10 | Si.; Ip-.47ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2929 | 10 | Si.; Ip-1.0ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2929A | 10 | Si.; Ip-1.0ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2930 | 10 | Si.; Ip-4.7ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2930A | 10 | Si.; Ip-4.7ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2931 | 10 | Si.; Ip-10ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2931A | 10 | Si.; Ip-10ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2932 | 10 | Si.; Ip-22ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2932A | 10 | Si.; Ip-22ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2933 | 10 | Si.; Ip-47ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2933A | 10 | Si.; Ip-47ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2934 | 10 | Si.; Ip-100ma±10pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| 1N2934A | 10 | Si.; Ip-100ma±2pct; Vp-.065; Ip/Iv-3.5min. | HSD |
| D4115 | 10 | 2000Mc microwave/switch | SYL |
| D4115A | 10 | 3000Mc microwave/switch | SYL |
| D4115B | 10 | 4000Mc microwave/switch | SYL |
| HU5 | UNI-TUNNEL | Si.; IF-.50ma min.; IR-5.0ua max at 0.-.508 | HSD |
| HU5A | UNI-TUNNEL | Si.; IF-.50ma min.; IR-5.0ua max at 0.-.508 | HSD |
| HU10 | UNI-TUNNEL | Si.; IF-1.0ma min.; IR-10ua max at 0.-.508 | HSD |
| HU10A | UNI-TUNNEL | Si.; IF-1.0ma min.; IR-10ua max at 0.-.508 | HSD |
| HU25 | UNI-TUNNEL | Si.; IF-2.5ma min.; IR-25ua max at 0.-.508 | HSD |
| HU25A | UNI-TUNNEL | Si.; IF-2.5ma min.; IR-25ua max at 0.-.508 | HSD |
| HU50 | UNI-TUNNEL | Si.; IF-5.0ma min.; IR-50ua max at 0.-.508 | HSD |
| HU50A | UNI-TUNNEL | Si.; IF-5.0ma min.; IR-50ua max at 0.-.508 | HSD |
| HU75 | UNI-TUNNEL | Si.; IF-7.5ma min.; IR-75ua max at 0.-.508 | HSD |
| HU75A | UNI-TUNNEL | Si.; IF-7.5ma min.; IR-75ua max at 0.-.508 | HSD |
| HU100 | UNI-TUNNEL | Si.; IF-10ma min.; IR-100ua max at 0.-.508 | HSD |
| HU100A | UNI-TUNNEL | Si.; IF-10ma min.; IR-100ua max at 0.-.508 | HSD |
| HF1000 | 10 | Ip;1-2ma; Ip/Iv-5min; Cd-15pF; Vp-49mV Vv-340mv; Freq. 500Mc. | HUG |
| HF1001 | 10 | Ip;1-2ma; Ip/Iv-7min; Cd-15pF; Vp-49mV Vv-340mv; Freq. 500Mc. | HUG |
| HF1002 | 10 | Ip;1.0±.05ma; Ip/Iv-8.5typ; Cd-10pF; Vp-49mV Vv-340mv; Freq. 500Mc. | HUG |
| HF1003 | 10 | Ip;5.0±.25ma; Ip/Iv-8.5typ; Cd-50pF; Vp-49mV Vv-340mv; Freq. 500Mc. | HUG |
| HF1004 | 10 | Ip;10±.50ma; Ip/Iv-8.5typ; Cd-100pF; Vp-49mV Vv-340mv; Freq. 500Mc. | HUG |
| HP310 | | Halltron Hall Effect Devices | OHI |
| HP315 | | Halltron Hall Effect Devices | OHI |
| HR31 | | Halltron Hall Effect Devices | OHI |
| HS51 | | Halltron Hall Effect Devices | OHI |
| MC1 thru MC5 | | Halltron Magnetic Circuit | OHI |
| MC11 thru MC15 | | Halltron Magnetic Circuit | OHI |
| MC21 thru MC25 | | Halltron Magnetic Circuit | OHI |
| PC5 | | Halltron Power Transducers | OHI |
| PC500 | | Halltron Power Transducers | OHI |
| TA11 | | Thermoelectric Coolers | OHI |
| TA20 | | Thermoelectric Coolers | OHI |

Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes
3. Varactor diodes
4. Photodiodes
5. Solar Cells
6. Harmonic generator diodes
7. 4-Layer bistable diodes
8. Controlled rectifier
9. PNPN switch
10. Tunnel diode
11. Photoconductive cell

# VOLTAGE VARIABLE CAPACITOR DIODES

| TYPE NO. | CAPACITANCE C @ Eb (uuf) | CAPACITANCE C @ Eb (volts) | PIV | Q @ FREQ. Min. Q | Q @ FREQ. (mc) | MFR. |
|---|---|---|---|---|---|---|
| D4140 † | 4.5 | 6.0 | | 1.0 | 10000 | SYL |
| D4140A † | 3.0 | 6.0 | | 2.0 | 10000 | SYL |
| D4140B † | 2.0 | 6.0 | | 3.0 | 10000 | SYL |
| D4140C † | 1.8 | 6.0 | | 4.0 | 10000 | SYL |
| D4140D † | 1.4 | 6.0 | | 5.0 | 10000 | SYL |

Under Type No.
† - Sub Miniature Glass
Ø - Miniature Pill Varactor
△ - Double-ended Varactor
* - Subminiature Ceramic

# VOLTAGE VARIABLE CAPACITOR DIODES

| TYPE NO. | CAPACITANCE C @ Eb (uuf) | (volts) | PIV | Q @ FREQ. Min. Q | (mc) | MFR. |
|---|---|---|---|---|---|---|
| D4140E † | 1.0 | 6.0 | | 6.0 | 10000 | SYL |
| D4141 * | 4.5 | 6.0 | | 1.0 | 10000 | SYL |
| D4141A * | 3.0 | 6.0 | | 2.0 | 10000 | SYL |
| D4141B * | 2.0 | 6.0 | | 3.0 | 10000 | SYL |
| D4141C * | 1.8 | 6.0 | | 4.0 | 10000 | SYL |
| D4141D * | 1.4 | 6.0 | | 5.0 | 10000 | SYL |
| D4141E * | 1.0 | 6.0 | | 6.0 | 10000 | SYL |
| SC47 | 470 | 4.0 | 25 | 100 | .10 | TRA |
| SC68 | 680 | 4.0 | 20 | 100 | .10 | TRA |
| SC82 | 820 | 4.0 | 20 | 100 | .10 | TRA |
| SC100 | 1000 | 4.0 | 25 | 100 | .10 | TRA |
| SC120 | 1200 | 4.0 | 20 | 100 | .10 | TRA |
| SC150 | 1500 | 4.0 | 20 | 100 | .10 | TRA |
| SC180 | 1800 | 4.0 | 20 | 100 | .10 | TRA |
| XD501 △ | .50 | 0 | 6.0 | 27 | 3000 | TI |
| XD502 △ | .50 | 0 | 6.0 | 36 | 3000 | TI |
| XD503 △ | .50 | 0 | 6.0 | 48 | 3000 | TI |

Under Type No.
† - Sub Miniature Glass
Ø - Miniature Pill Varactor
△ - Double-ended Varactor
* - Subminiature Ceramic

## SWITCHING DIODES

| TYPE NO. | MAT | PIV (volts) | MAX. CONT. REV. WORK. VOLT. (volts) | Min. Forward Current @ 25°C $I_f$ (mA) | $@ E_f$ (volts) | MAX. REVERSE CURRENT @ 25°C $I_b$ (µa) | $@ E_b$ (volts) | Recovery Characteristics TEST CONDITIONS Fwd. $I_f$ (ma) | Rev. to $E_b$ (volts) | $Z_{rec.}$ (K ohms) | @ time (t) (usec) | MFR. (See code at start of charts) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1N3125 | Ge | 55 | 40 | 5.0 | .40 | 100 | 40 | 5.0 | 20 | 50 | .30 | SYL |
| HD2963 | Ge | 7.0 | | | | 10 | 5.0 | 10 | 6.0 | 2.0 | 6.0m | HUG |
| HD2964 | Ge | 20 | | | | 10 | 5.0 | 10 | 6.0 | 2.0 | 3.0m | HUG |
| HD2967 | Ge | 4.0 | | | | 40 | 2.5 | 3.0 | 3.0 | 1.0 | 6.0m | HUG |
| HD2968 | Ge | 6.0 | | | | 40 | 2.5 | 10 | 6.0 | 1.0 | 4.0m | HUG |
| HD5000 | Si | 20 | | 5.0 | 1.0 | .20 | 5.0 | 10 | 6.0 | | .50m max | HUG |
| HD5001 | Si | 20 | | 5.0 | 1.0 | 1.0 | 5.0 | 10 | 6.0 | | .50m max | HUG |
| HD5002 | Si | 20 | | 2.0 | 1.0 | .20 | 5.0 | 10 | 6.0 | | .50m max | HUG |
| HD5003 | Si | 20 | | 2.0 | 1.0 | 1.0 | 5.0 | 10 | 6.0 | | .50m max | HUG |
| HD5004 | Si | 15 | | 2.0 | 1.0 | 1.0 | 5.0 | 10 | 6.0 | | .50m max | HUG |

**The following manufacturers have announced that they have begun supplying the indicated previously registered devices.**

BRADLEY SEMICONDUCTOR:
1N256, 1N316, 1N316A, 1N359, 1N359A, 1N365, 1N440, 1N440B, 1N441, 1N441B, 1N530, 1N531, 1N550, 1N1199A thru 1N1206A, 1N1341A thru 1N1348A, 1N1488, 1N1560, 1N1696, 1N2080, 1N2085, 1N2216, 1N2217, 1N2258,1N2258A, 1N2259,1N2259A,1N2491 thru 1N2497,1N2512 thru 1N2523, 1N2847 thru 1N2864

FANSTEEL METALLURGICAL:
1N248B,1N249B,1N250B,1N1183 thru 1N1190,1N1199 thru 1N1206,1N1396 thru 1N1403,1N1612 thru 1N1616

OHMITE:
1N34, 1N34A, 1N36, 1N38, 1N38A, 1N38B, 1N39A, 1N39B, 1N40 thru 1N52, 1N52A, 1N54, 1N54A, 1N55, 1N55A, 1N55B, 1N56, 1N56A, 1N57, 1N58, 1N58A, 1N59, 1N60, 1N60A, 1N61 thru 1N71, 1N67A thru 1N70A, 1N73, 1N74, 1N75, 1N81, 1N81A, 1N83, 1N84, 1N86, 1N87A, 1N88, 1N89, 1N90, 1N95 thru 1N104, 1N96A thru 1N100A, 1N107, 1N108, 1N111 thru 1N120, 1N116A, 1N117A, 1N118A, 1N126, 1N126A, 1N127, 1N127A, 1N128, 1N128A, 1N132, 1N139 thru 1N145, 1N191, 1N192, 1N198, 1N198A, 1N265 thru 1N268, 1N270, 1N273, 1N276 thru 1N279, 1N281, 1N283, 1N287 thru 1N292, 1N294, 1N295, 1N297, 1N297A, 1N298, 1N298A, 1N304 thru 1N310, 1N312, 1N313, 1N314, 1N355, 1N367, 1N417, 1N418, 1N419, 1N435, 1N447 thru 1N455, 1N476 thru 1N480, 1N490, 1N497 thru 1N502, 1N527, 1N541, 1N542, 1N566 thru 1N569, 1N571, 1N616, 1N617, 1N631 thru 1N636,1N695,1N698,1N699,1N770 thru 1N776,1N771A thru 1N774A, 1N771B, 1N805, 1N1093, 1N1170

TEXAS INSTRUMENTS:
1N536, 1N537

TRANSITRON ELECTRONIC:
1N429, 1N702 thru 1N716, 1N708A thru 1N716A, 1N746A thru 1N759A, 1N914, 1N916, 1N1765 thru 1N1802, 1N1765A thru 1N1802A, 1N1803R thru 1N1815R, 1N1803RA thru 1N1815RA

U.S.SEMICONDUCTOR:
1N332 thru 1N349, 1N550 thru 1N555, 1N562, 1N563, 1N607 thru 1N614, 1N607A thru 1N614A, 1N711A thru 1N738A, 1N763A thru 1N769A, 1N1115 thru 1N1120, 1N1124 thru 1N1128, 1N1199 thru 1N1206, 1N1341 thru 1N1348, 1N1537 thru 1N1544

# CUMULATIVE INDEX—1960

## INDEX OF ARTICLES



(*Continued on next page*)

# CUMULATIVE INDEX—1960

*(Continued)*

## INDEX OF AUTHORS

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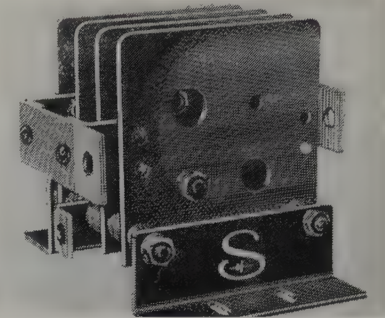
# New Products

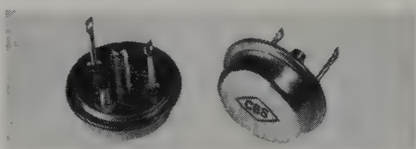
### Stack Assembly



A new single phase, full-wave bridge assembly featuring a full range of circuit configurations has been introduced by Standard Rectifier Corporation. Measuring 4-13/32″ x 4-1/4″ x 3-21/32″ the unit is designed for either forced air or natural convection cooling. The assembly has 3 x 3 x .047″ copper plates. Additional stacks are available for rectifiers of six amperes through 400 amperes and in both series and parallel combinations.

Circle 188 on Reader Service Card

### High-Power Transistors




A single new 85-watt *p-n-p* power transistor saves space and weight by replacing two 40-watt or four 20-watt paralleled transistors according to CBS Electronics, who has announced nine new types in this high-power class. These transistors can provide 30 watts Class A, 100 watts Class B, or 1000 watts switching. Collector voltages up to 100 volts are available. A large signal current gain of 70 at 5 amperes collector current can be achieved. Maximum working current of 15 amperes is permissible for all types.

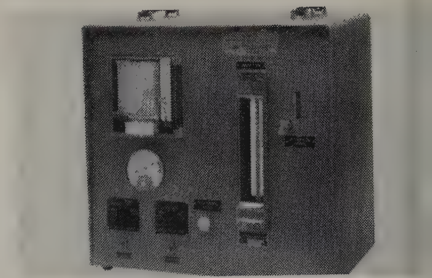
Circle 184 on Reader Service Card

### Rectifier Test Set

A new test set for life testing semiconductor rectifiers is announced by Wallson Associates, Inc. Model 154 Power Supply, a self-contained unit, is applicable to incoming inspection, on-line inspection and laboratory use. Supplying 32 amperes average rectified *d-c* with inverse voltage from 0 to 1000 volts peak, it will test 32 one-amp rectifiers, two 16-amp rectifiers or any combination in terms of rated capacity. Provisions are also made for testing one 25-ampere unit. Power input is 120 v, 60 cps, 350 watts.

Circle 182 on Reader Service Card

### Moisture Analyzers



Meeco Instruments offers three new types of Electrolytic Moisture Analyzers for the electronics and semiconductor industries. They are now available for measurement and control of the dryness of gases in dry boxes, gas lines, dryers and furnaces.

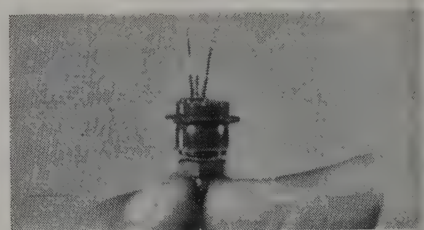
Circle 187 on Reader Service Card

### New Flux Discovery

Metal surfaces normally resistant to fluxing can now be soldered with a new printed circuit liquid rosin flux produced by Alpha Metals, Inc. Alpha 346-35 has been found to work well with a wide group of metals: brass, bronze, cadmium plate, copper, lead nickel plate, silver, solder plate, terne plate, hot-dipped tin, electrolytic tin plate, tin-zinc plate. Density is .901 g/ml; flash point 78° F; boiling point 177° F; 35% solids.

Circle 185 on Reader Service Card

### Medium-Power Transistors



Minneapolis-Honeywell Regulator Company has expanded its activities in the transistor field with introduction of a line of miniaturized medium-power transistors. Previously the firm manufactured high-power triode and tetrode transistors exclusively. The new transistors feature high-frequency response and low leakage current characteristics and are said to remain stable over long periods while dissipating heat. Less than ½″ in diameter, the units are stud-mounted in a cold-weld package with flexible leads. They are capable of dissipating 15 watts at 25° C case temperature.

Circle 181 on Reader Service Card

### High-Current Adapter

Designed specifically for use with a Tektronix Type 575 Transistor-Curve Tracer, the Type 175 Adapter provides 200-ampere collector displays, three ranges of collector supply, and 12-ampere base supply. It enables the Transistor-Curve Tracer to plot and display on its crt the characteristic curves of high-powered transistors. Used with the 575, the Adapter allows observation and measurement of characteristic curves of both *n-p-n* and *p-n-p* transistors, and diodes. Generally, for transistors, a family of collector-current curves can be plotted to 200 amperes or more. (For diodes, curves can be plotted to 100 amperes or more.)

Circle 183 on Reader Service Card

(*Continued on page* 64)

# Market News . . .

### Sales

Shipments of electronic components by U.S. manufacturers reached another all-time high during the first quarter 1960, according to the Electronics Division, Business and Defense Services Administration, U.S. Department of Commerce.

| Category | Quantity (in thousands of units) | | | Value (in millions of dollars) | | |
|---|---|---|---|---|---|---|
| | Total | Military | Non-military | Total | Military | Non-Mil |
| SEMICONDUCTOR DEVICES | 73,430 | 22,499 | 50,931 | 136.6 | 66.4 | 70.2 |
| Diodes, rectifiers and related devices | 40,550 | 16,112 | 24,438 | 53.3 | 27.6 | 25.7 |
| Germanium diodes and rectifiers | 20,428 | 7,841 | 12,587 | 11.9 | 6.0 | 5.9 |
| 0-30 ma | 10,442 | 3,848 | 6,594 | 5.8 | 3.1 | 2.7 |
| 31-100 ma | 8,537 | 3,480 | 5,057 | 4.7 | 2.4 | 2.3 |
| Over 100 ma | 1,449 | 513 | 936 | 1.4 | 0.5 | 0.9 |
| Silicon diodes and rectifiers | 17,127 | 7,323 | 9,804 | 31.1 | 16.9 | 14.2 |
| 0-30 ma | 1,074 | 579 | 495 | 2.5 | 1.7 | 0.8 |
| 31-100 ma | 4,866 | 2,984 | 1,882 | 10.0 | 6.5 | 3.5 |
| 101-550 ma | 6,039 | 2,139 | 3,900 | 8.4 | 4.0 | 4.4 |
| 551 ma—3 amps | 3,635 | 1,294 | 2,341 | 5.3 | 2.5 | 2.8 |
| Over 3 amps—35 amps | 1,380 | 265 | 1,115 | 2.8 | 1.1 | 1.7 |
| Over 35 amps | 133 | 62 | 71 | 2.1 | 1.1 | 1.0 |
| Zener diodes | 1,379 | 528 | 851 | 6.1 | 2.4 | 3.7 |
| Microwave diodes | 282 | 198 | 84 | 1.2 | 0.9 | 0.3 |
| Infra-red and other semiconductor photo cells, except solar cells | 65 | 48 | 17 | 0.6 | 0.5 | 0.1 |
| Other[1] | 1,269 | 174 | 1,095 | 2.4 | 0.9 | 1.5 |
| Transistors | 32,880 | 6,387 | 26,493 | 83.3 | 38.8 | 44.5 |
| Germanium | 30,823 | 4,827 | 25,996 | 58.3 | 20.3 | 38.0 |
| 0-125 mw | 13,214 | 2,921 | 10,293 | 24.4 | 11.2 | 13.2 |
| 126-999 mw | 12,199 | 1,391 | 10,808 | 22.6 | 5.9 | 16.7 |
| 1 watt and over | 5,410 | 515 | 4,895 | 11.3 | 3.2 | 8.1 |
| Silicon | 2,057 | 1,560 | 497 | 25.0 | 18.5 | 6.5 |

[1]Includes diodes and rectifiers made from materials other than silicon and germanium, tunnel diodes, controlled rectifiers, solar cells, and other special semiconductor devices which must be combined to avoid disclosure of proprietary information.

Japanese transistor exports to the United States for the first six months of 1960, which increased sharply in 1959, have increased only nominally in quantity but were up 21% by value.

| | Quantity in thousands of units | | | | Value in thousands of dollars | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Jan-June | | | | Jan-June | |
| | 1958 | 1959 | 1959 | 1960 | 1958 | 1959 | 1959 | 1960 |
| Transistors | 11 | 2393 | 823 | 832 | 7 | 1581 | 521 | 631 |
| Other semiconductor devices | | 597 | 280 | 56 | | 92 | 42 | 9 |

EIA's statistics showed factory sales of transistors to have recovered during August from a sharp down-turn in July. The numbers of units sold exceeded 9.7 million, a total more than 2.6 million higher than the July figure. August revenue totaled over $22.7 million, more than $4.6 million over the total for July.

Transistor Sales

| | Factory Sales (Units) | Factory Sales (Dollars) |
|---|---|---|
| August | 9,732,993 | $22,739,969 |
| July | 7,070,884 | 18,083,802 |
| June | 10,392,412 | 27,341,733 |
| May | 9,046,237 | 24,146,373 |
| April | 9,891,236 | 23,198,576 |
| March | 12,021,506 | 28,700,129 |
| February | 9,527,662 | 24,831,570 |
| January | 9,606,630 | 24,714,580 |
| Year-to-date '60 | 77,289,560 | 193,756,732 |
| Year-to-date '59 | 49,257,987 | 133,486,228 |

### Prices

Texas Instruments, Inc. has just completed an experimental promotion plan in New England offering five free 2N1038 germanium medium power transistors with the purchase of ten 2N1039 germanium transistors. The 2N1039 sells for $3.75 each and the 2N1038 normally sells for $2.85 each.

Sylvania Electric Products, Inc. Semiconductor division has made available a matched pair of silicon microwave mixer diodes. In quantities of 1-99 type 1N53D is priced at $75 each and its reversed polarity version type 1N53RD at $110 each.

Hughes International, U.K., Ltd., has reduced prices on its silicon diodes produced in Glenrothes, Scotland. One diode in their H range has been reduced from 95¢ to 50¢. Another has been reduced from $1.75 to $1.12.

Semiconductor division, General Instrument Corp. has available a series of 10w Zener diodes. Type 1N1808 is priced at $8.35 each in quantities less than one hundred and at $6.25 each in 100-999 quantities. Types 1N2044 through 1N2049 and types 1N1351 through 1N1362 are priced the same as the 1N1808.

Raytheon Co.'s Semiconductor Division is now marketing new subminiature germanium alloy transistors measuring 0.13 x 0.13 inches. Types 2N799, 2N805, 2N811, 2N813, 2N815 and 2N821 are priced between $1.90 to $5.50 in 100 to 999 units each.

Minneapolis-Honeywell Regulator Co. is now producing medium power transistors. Type 2N1658 is selling at $6 each in quantities of 100 to 999 and type 2N1659 for $4.50 each in the same quantities.

Semi-Elements Inc., Saxonburg, Pa. has developed two diodes for UHF circuitry. The price of these in quantities of 100 to 999 is 59¢ each. In quantities of 1000 or more they cost 52¢ each.

### Suppliers

Crys-Tech Inc., Santa Ana, Cal. is now producing doped single GaAs at $32 per gram and undoped material at $30 per gram. The firm plans to make price reductions and quality discounts in the near future. Zinc-doped *p* type GaAs ingots are available in resistivities from 0.07 down to 0.005 ohm/cm.

Solid State Materials Corp., Needham Heights, Mass. is marketing GaAs at $20 a gram. The company is considering dropping this price if large quantities are purchased.

### Distributors

Schweber Electronics, national components specialist distributor, recently sponsored the Schweber Electronics Exposition, a three-day preview of products forthcoming in 1961 from the manufacturers they represent. The trade show was held at the distributor's headquarters in Mineola, L.I., N.Y. from November 28th through November 30th. The show also commemorated the official opening of a new wing of the Schweber Building, increasing the company's stocking facilities to 17,000 square feet.

General Instrument Corp. has appointed Arrow Electronics Inc., Mineola, N.Y. as a distributor of its semiconductor products to the military and commercial fields.

Newark Electronics has placed orders with Texas Instruments Inc. for diodes and rectifiers which total around $500,000 under Texas Instruments' distributor price protection policy.

Rheem Semiconductor Corporation, Mountain View, California, has appointed three new distributors. Those appointed are L. B. Walker Radio Company, Denver, Colorado; Moore Radio Supply, Inc., Salt Lake City, Utah; and Summit Distributors, Inc., Buffalo, New York. These distributors carry the complete Rheem line of silicon diodes and silicon mesa transistors, including all the microminiature transistors in the MICROBLOC series. Quantities offered are: diodes 1 to 4,999; transistors 1 to 999.

### New Firm

Micro State Electronics Corporation has been formed to do research, development and production in the microwave and solid state fields. The company is already in operation in temporary quarters at 15 Brown Avenue, Springfield, N. J., while awaiting completion of a new permanent plant in New Providence, N. J., scheduled for December 15. Micro State Electronics will center its activity in the areas of low noise amplifiers, solid state oscillators and microwave semiconductor devices.

# Industry News

### CONFERENCE CALENDAR

**The Following January 1961 Meetings Are Scheduled:**

Jan 8-12 Symposium on Thermoelectric Energy Conversion, Statler Hotel, Dallas, Texas. Sponsored by PGED, ANS, AIEE, AIME, et al. For Information: Philip Klein, General Electric Co., Syracuse, N. Y.

Jan 9-11 7th National Symposium on Reliability & Quality Control, Bellevue-Stratford Hotel, Philadelphia, Pa. Sponsored by PGRQC, ASQC, AIEE, EIA. For Information: R. E. Kuehn, Inst. for Defense Analyses, Pentagon, Washington, D. C.

January Conference on Magnetic & Dielectric Devices, LMSD, Palo Alto, Calif. Sponsored by PGED, AIEE. For Information: A. K. Wing, ITT Labs, Nutley 10, N. J.

Jan 12-13 Unclassified Conference on Reliability of Semiconductor Devices, Western Union Auditorium, 60 Hudson St., NYC. Sponsored by the Working Group on Semiconductor Devices of the Advisory Group on Electron Tubes. For Information: Advisory Group on Electron Tubes, 346 Broadway, New York 13, N. Y., Att: Secretary, Working Group on Semiconductor Devices.

Jan 17-19 ISA Winter Instrument-Automation Conference & Exhibit, Sheraton-Jefferson Hotel & Kiel Auditorium, St. Louis, Mo. Sponsored by ISA. For Information: Wm. H. Kushnick, Executive Director, ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

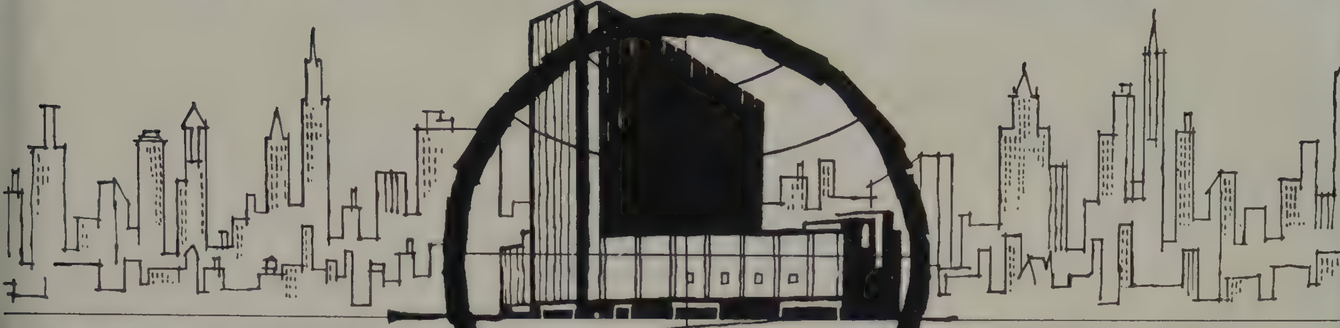
Jan 31-Feb 1-2 8th Cleveland Electronics Conference, Cleveland Engineering & Scientific Center, Cleveland, Ohio. Sponsored by Cleveland Electronics Conference, Inc. For Information: Lapine Enterprises, Hotel Manger, Cleveland 14, Ohio.

### RESEARCH AND DEVELOPMENT

General Instrument Corporation recently announced receipt of a contract from the Atomic Energy Commission for the initial research which may lead to a first-of-its-kind thermoelectric generator designed to produce electricity directly from heat of fission products produced in nuclear reactors. The work being done by the Corporation is part of the AEC's SNAP (Systems for Nuclear Auxiliary Power) program. The contract calls for an investigation and report on the heat characteristics of the "unrefined fission products" of various A.E.C. plants, as they could be used to power such a generator. Such thermoelectric generators, which have no moving parts to wear out or fuel supply to replenish, could provide a low cost, ultra-reliable and continuous source of power for communications and control equipment in remote areas. The company's Thermoelectric Division currently has a

(*Continued on page* 62)

# NEW YORK · WORLD CENTER FOR RADIO-ELECTRONICS · 1961



## INTERNATIONAL IRE SHOW CONVENTION

Visitors from all over the world will converge on the Coliseum, March 20-23, for IRE's big Show and International Convention. Join the more than 65,000 radio-electronics engineers who will attend! □ On the Coliseum's 4 gigantic floors you'll see the latest production items, systems, instruments and components in radio-electronics; in radar; in complex air traffic control; in space communications—in any and every field of radio-engineering you care to name. □ At the convention, you'll trade ideas with brilliant delegates from the world of radio-electronics, and choose from amongst scores of papers to be read by experts in their field. Like the IRE show, the convention is both a summing-up and a look into the future! *Remember the occasion, the time, the place.*

Registration: IRE members $1.00—non-members $3.00

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MARCH 20-23 1961
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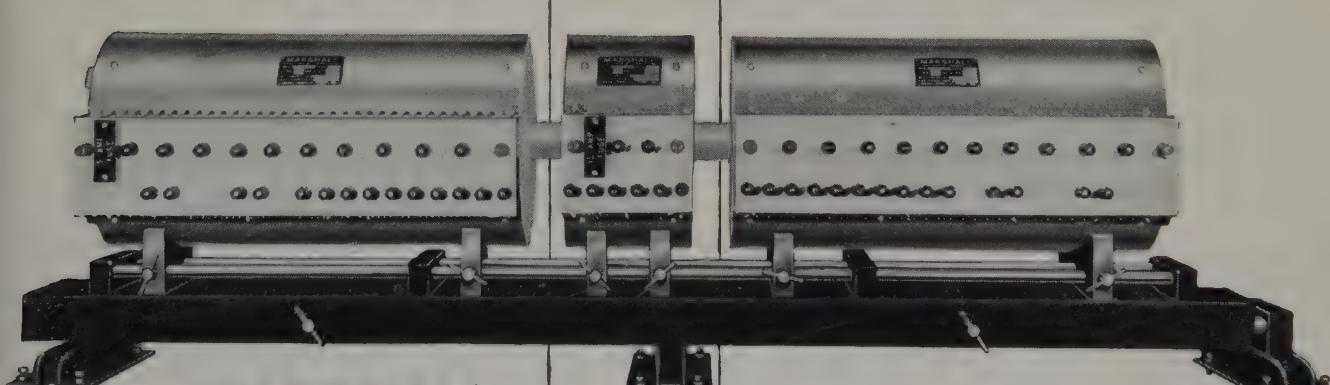
No one under 18 years of age will be admitted.

# NEW!

*Typical combination for preparing gallium arsenide consists of 2 furnaces 2"ID x 10"OD x 20" and 1 furnace 2"ID x 10"OD x 6". Note adjustable spacing between furnaces, Thomson rods and ball bushings for linear motion of entire unit.*



## MARSHALL furnace apparatus for SEMI-CONDUCTOR PRODUCTION

***...permits zone refining and directional freezing***

Model 60-SC furnace apparatus is designed for semiconductor preparation and growing single crystal materials. It consists of two or more tubular furnaces mounted on a common axis with a quartz reaction tube running through all furnace chambers. This arrangement permits zone refining and directional freezing of most semi-conductor materials. Furnaces are available in temperature ranges to 1400° C., can maintain uniform zones of ±1° C., and have sufficient shunt taps to establish any reasonable temperature profile within the chamber. Furnaces can be spaced to establish sharp temperature gradients between adjoining units, and can be driven in tandem along the support stand at speeds from 1/8" to 9" per hour. Marshall can supply the complete package of appropriate furnaces, support stand, drive unit, and temperature controls, for horizontal operation (shown above) or in vertical position for "Bridgman Drop" experiments. Ask for specification sheet 825-A.

**Marshall Products Co.** *tubular furnaces and control panels*
270 W. LANE AVENUE, COLUMBUS 2, OHIO

Circle No. 32 on Reader Service Card

*(from page* 60)

number of thermoelectric generators under development and is also working on other thermoelectric equipment based on the Peltier effect (direct conversion of electricity into cooling system) for refrigeration and air conditioning applications.

Radio Frequency spectroscopy will soon be speeding fluorine and hydrogen analysis at Dow Chemical's Midland, Michigan plant, with the company's purchase of a Schlumberger Model 106 NMR Analyzer. Capable of determining the hydrogen or fluorine content of a sample in seconds by a non-destructive method known as wide-line nuclear magnetic resonance, the instrument will be used in the general analytical laboratory for routine quantitative analyses. The analyzer, developed by Schlumberger's Ridgefield Instrument Group, is equipped for rapid switch-over from one element to another. NMR is a spectroscopic technique based on the absorption of radiofrequency (RF) energy by certain elements when they are placed in a strong magnetic field.

A 94% improved margin for uniformity and closer tolerance is permitted under a new patent issued for the fabrication of spheroids used in transistor manufacturing. The patent has been assigned to The Indium Corporation of America, Utica, New York, by Timothy J. Rowan, according to an announcement by William N. Macartney, president of The Indium Corporation. Licenses to operate under this new patent are being granted by the company. In the patented method, punchings and platelets can be held to 2% of difference in weight and, therefore, the spheroids may be only 2% under or over the weight desired.

Heretofore, many transistor producers have allowed a mass of a sphere to be 35.25% over the weight desired or 27.1% under weight. This resulted from the grading by sieves or micrometer rolls which did not give close enough sizing. Spheres were made by dropping molten metal into a column of liquid hot enough at the top to keep the metal molten and cool enough at the bottom to solidify the resulting spheroids.

Under the new system, punchings or platelets are made from uniformly thick ribbon or plate and are then spheroidized in a column of suitable liquid hot enough at the top to melt the punchings or platelets and cold enough to make the spheroids solid. In this manner, spheroidal particles are made of the same weight. These particles are then used in transistors which are made from emitter and collector dots diffused from opposite sides into a semiconductor material such as germanium.

One of Japan's major electrical manufacturers has made a technical breakthrough in the manufacturing process of silicon rectifiers. The new technique, according to the company, eliminates the need for costly molybdenum or tungsten for certain types of silicon rectifiers. Research workers of the Tokyo Shibaura Electric Company, or Toshiba, as the company is generally known, have developed a method of soldering materials for electrodes, such as copper or silver, directly onto the silicon rectifier element. Hitherto, it has been necessary to use a "buffer" material between the copper or silver and the silicon element.

The new method, the company further states, greatly reduces costs, simplifies the manufacturing process, and substantially increases the performing efficiency of such rectifiers.

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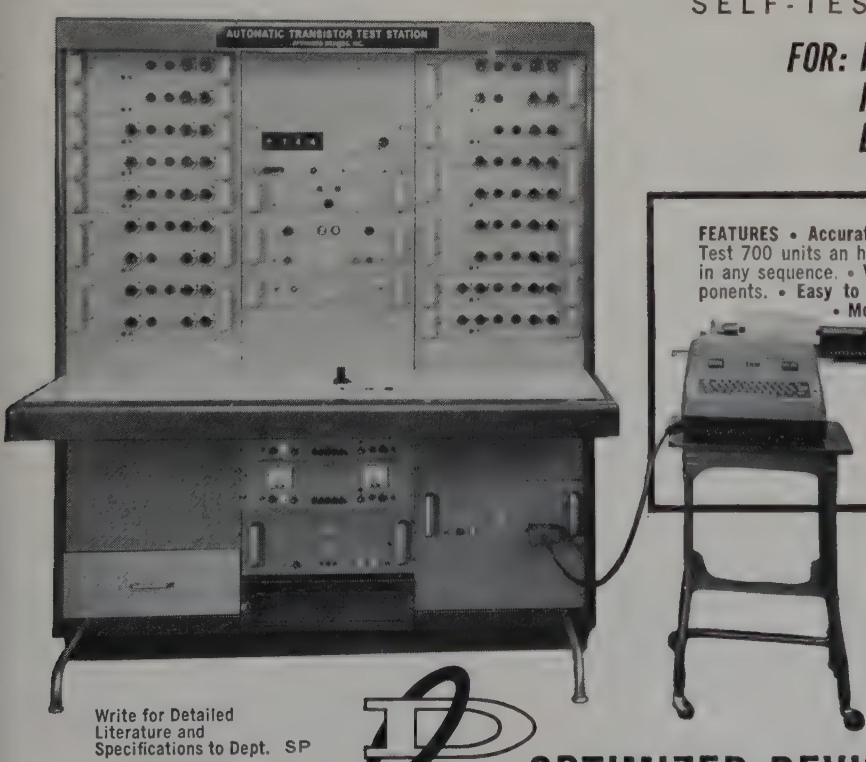


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## New Products

*(from page 58)*

### Switching Transistor

A new *n-p-n* high speed germanium alloy switching transistor, a mate for Type 2N404A, has been announced by Sylvania. Type 2N1605A, offers extra collector-to-base voltage (40V max) for high voltage circuitry, low reverse leakage voltage (10 ua max) at 40V, maximum power dissipation of 200 mw at 25° C, and junction temperature ratings of —65° C to +100° C. It is designed in a TO-5 JEDEC package with base connected to metal case.

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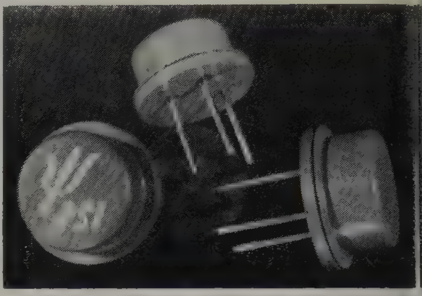
### Power Transistors



A silicon power transistor, PT 530, announced recently by Pacific Semiconductors, Inc., has a power output of 5 watts at 30 megacycles with a power gain of 10 db minimum at collector voltage of 28V, and delivers useful oscillator power to 200 mc. According to the company, the superior power output and frequency capabilities of the transistor are the result of a fabrication technique developed by them which lends itself to precise control of the diffused regions and to the accurate definition of device geometry.

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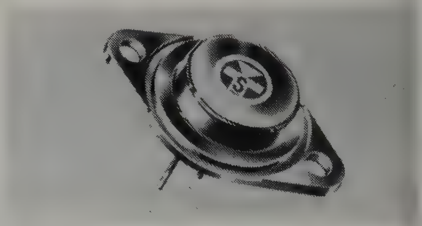
### High Power Silicon Transistors



A new series of transistors was announced by Silicon Transistor Corp. recently. 2N1487, 2N1488, 2N1489, and 2N1490, are diffused junction, *n-p-n* high power silicon transistors. Temperature range is from —65°C to +175°C. Power dissipation at mounting flange temperature of 25°C is 60 watts. These types feature a high beta and low saturation resistance. The range of beta for 2N1489 and 2N1490 is from 25 to 75 with saturation resistance of max. .67 ohms measured at 1.5 amps.

Circle 163 on Reader Service Card

### Inserts For Transistor Firing Boats

American Lava Corp. Inserts made of AlSiMag 614 alumina ceramic have proved to have almost unlimited life when used repeatedly in fusion firing boats. These inserts accurately position the metallic dots in relation to the silicon or germanium wafer during the furnace operation. They have great resistance to wear and can be used safely in operating temperatures used in normal firing. Custom made inserts can be made with the required dimensional accuracy.

Circle 173 on Reader Service Card

### Ultra-Fast Computer Diodes

A new gold-bonded silicon diode with a guaranteed recovery time of half a nanosecond is now being produced by the semiconductor division of Hughes Aircraft Company. According to the company, a new technological breakthrough in the formation of the junction will enable circuit designers to boost computer speeds to levels previously unattainable. In development tests the computer diode switched from ten milliamps forward current to minus six volts reverse voltage with less than 0.2 nanoseconds recovery time. Typical capacitance for the total diode is 0.7 picofarads. It also has a rectification efficiency of 25% at 13.5 Kmc.

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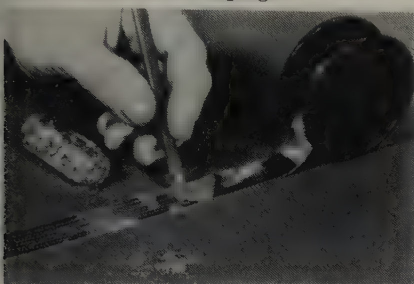
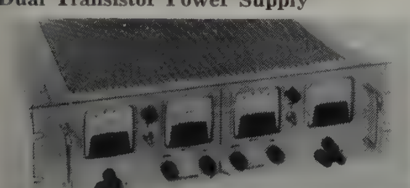
### Clad Metals and Stampings



Accurate Specialties Co., Inc., is now producing clad metal raw materials and stampings for semiconductor and other applications. The clad metals consist of an overlay of a low-melting point solder clad on one or both sides of a base material. The new process, the company states, eliminates the problem of de-wetting. Clad metal stampings using this new raw material have been generally applied in semiconductor work as base tabs used in effecting ohmic junctions.

Circle 193 on Reader Service Card

### Dual Transistor Power Supply



Trygon Electronics announces the availability of a highly regulated, dual output transistorized power supply Model 2s36-1.5. This new addition to the Silver Trygon line furnishes two independent 0-36 volts @ 0-1.5 amps outputs with 0.01% regulation and less than 1mv ripple. All power transistors have been pre-aged for at least 500 hours in order to optimize their reliability. Electrolytic capacitors are of computer quality thus allowing an operating ambient temperature up to 50° C and a storage temperature up to 85° C.

Circle 186 on Reader Service Card

### Precision Welding Head

Weldmatic Division of Unitek Corporation has introduced Model 1038, a new precision Welding Head capable of performing single, series or parallel welds for electronic components assembly; joining fine wire, ribbon and foils; and for applications requiring a controllable fastening technique without the use of an interconnecting or bonding material. Operable with a complete range of stored-energy power supplies, it features 500 watt-second power rating; foot-pedal actuation; precisely controllable electrode pressure and automatic firing.

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# New Literature

A buyers and engineers guide to aid in the selection of Fairchild Diffused Silicon Transistors and Diodes has been prepared by Schweber Electronics. A two-color, four page folder, it gives quick-reference details of function, performance, characteristics, etc. Also included is information on latest additions to the Fairchild line.

Circle 101 on Reader Service Card

The Sperry Semiconductor Division of Sperry Rand Corporation has released specification sheets on its new SD series of 250 ma and 400 ma subminiature Silicon Diodes. The data sheets list the electrical specifications, including maximum ratings and characteristics, of both the 250 and 400 milliampere types. Regulation curves, temperature derating curves and surge current are provided and physical description shown.

Circle 102 on Reader Service Card

Tektronix 8-page pamphlet gives a detailed presentation of Type 519 Oscilloscope, a calibrated, high-speed, laboratory instrument designed for observation, measurement, and photographic recording of wideband phenomena. The pamphlet includes specifications, block diagrams, and performance details, with schematic diagrams and waveform patterns for various measurement applications.

Circle 103 on Reader Service Card

Water-cooled baffles for use in high vacuum systems are described in new literature published by the manufacturer, Vacuum-Electronics Corp. Baffles covered in the new Veeco literature utilize solid brass bodies. The internal copper disc and body are water cooled for excellent heat conduction. The assembly is silver soldered to maintain heat conduction properties and nickel plated to assure non-corroding, clean surfaces.

Circle 104 on Reader Service Card

A new 16-page silicon rectifier short form catalog has been released by Standard Rectifier Corp. Complete with illustrations, specifications and drawings, it covers SRC's complete line of silicon power rectifiers. Specification data on more than 80 separate rectifier units with range of 50 to 600 volts PIV, and ½ through 400 amperes is detailed.

Service 105 on Reader Service Card

Engineers and purchasing agents active in the electronics industry may receive a free subscription to the Milgray Newsletter, according to Herbert S. Davidson, Milgray/New York president. Milgray Electronics, Inc. is an exclusive O.E.M. distributor of semiconductors and other electronic components. The Newsletter, published monthly as an industry service, is a 4-page, 2-color, well illustrated bulletin that includes reports and reviews of recent electronics products plus other news of interest to engineers and purchasing agents employed by manufacturers of original equipment.

Circle 107 on Reader Service Card

The new Hayes Recirculating Molecu-Dryer Type MS-RD complete with atmosphere recirculating unit, and designed specifically around Linde Company's 5A Molecular Sieve adsorbent material, is described in a recent bulletin published by C. I. Hayes, Inc. The illustrated bulletin lists numerous applications, such as "dry box" assembly of transistors and other electronic parts, and shows how this economical-to-operate, high-capacity adsorptive unit can easily be incorporated into a close cycle processing system.

Circle 106 on Reader Service Card

Composite Industrial Metals, Inc., manufacturers of solid and laminated materials for the semiconductor and electronics industries, has recently announced the availability of a new catalog which introduces C-I-M's facilities, describes their ability to serve and contains precious, non-precious, metal solder and base metal selection tables. This brochure includes line drawings of a number of laminated materials and part designs as well as many clarifying features about how to order laminates for maximum accuracy.

Circle 108 on Reader Service Card

Electronic Transistors Corp. announces the publication and availability of its new Interchangeability Chart which lists all Japanese-made radio transistors and the company's own American-made replacements. Over 100 different transistor types, used in virtually every Japanese-made transistor radio, and their American counterparts are included in the chart.

Circle 109 on Reader Service Card

Seven Hi-Lo Temperature Test Chambers are featured in Hotpack's newest Controlled Temperature Bulletin. The four page bulletin includes photographs of all the units, technical data, prices and complete specifications. The instructions and operation of the new test chambers are also included with optional features offered for each unit.

Circle 110 on Reader Service Card

Vitro Chemical Company recently announced the availability of technical data on "The Use of Rare Earths and Their Allied Elements in Dielectric Ceramic Materials." Vitro Chemical, a subsidiary of Vitro Corporation of America, is a leading producer of rare earths for glass and plastic polishing. The company produces a complete ine of inorganic chemical products for industry, and uranium concentrates for the Atomic Energy Commission.

Circle 111 on Reader Service Card

# INDEX TO ADVERTISERS

*For reference purposes, the advertisers index includes all regular advertisers who have run within the current contract year. These advertisers who appear in this issue are indicated by the page number adjacent to their listing, and are shown in a bold-face type.*



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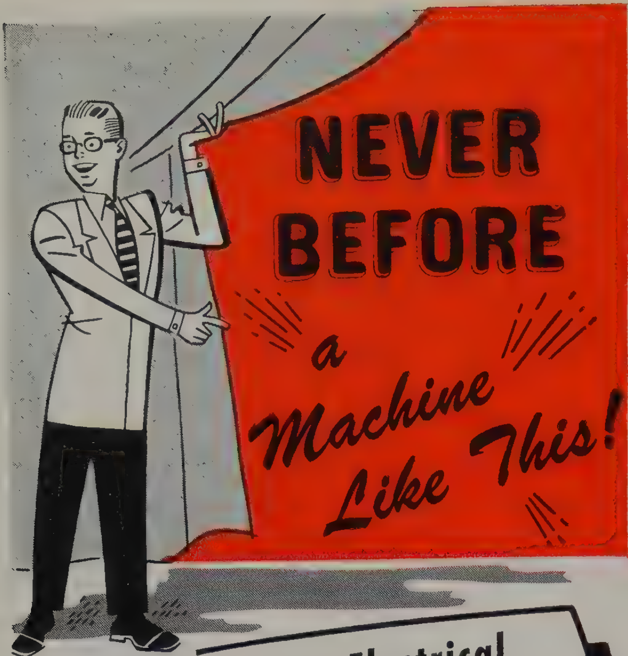


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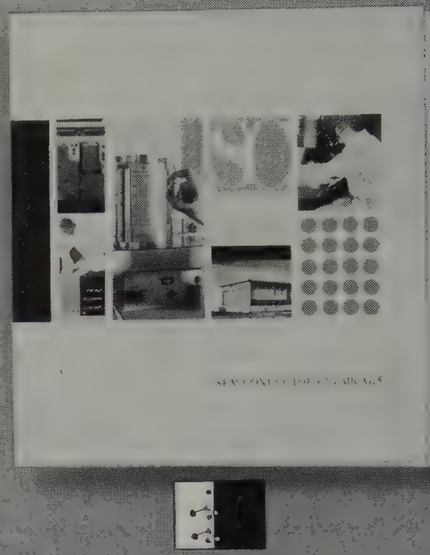

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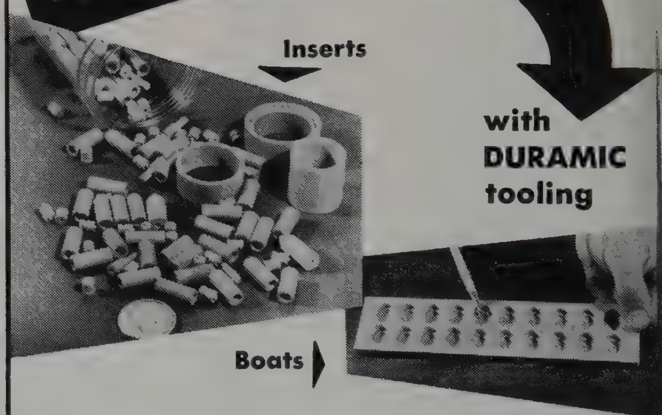


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*(Continued on Pg 72)*

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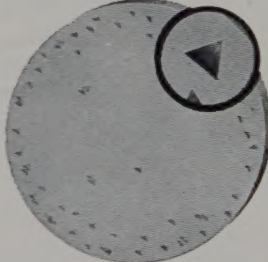

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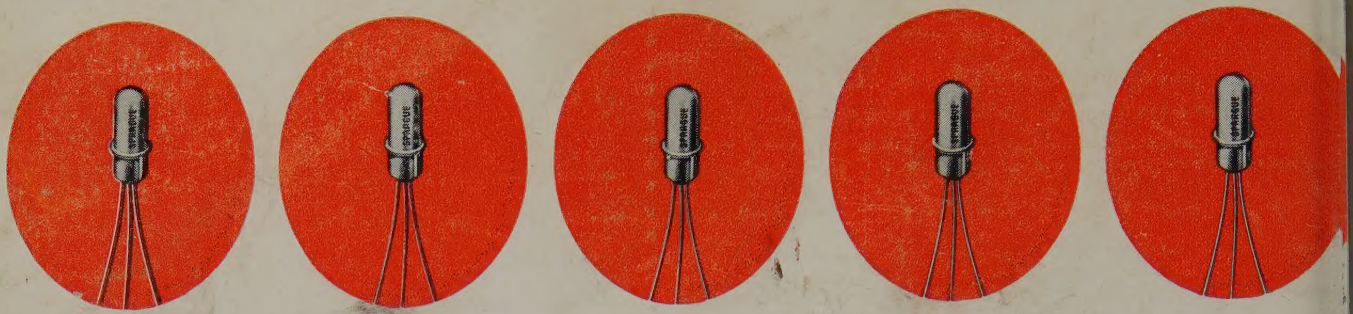

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